Requirements for Model-Centric Design

Roadway Design Division

August 2021

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Preface

The ***Requirements for Model-Centric Design*** document is intended to be a guide and reference point for TDOT staff and designers while transitioning to Bentley's OpenRoads Designer (ORD) CONNECT Edition software. There are certain sections of this document which may be beneficial to additional targeted audiences including TDOT's IT Division as well as consultants. This guide outlines general information and terminology associated with the software for legacy/existing project conversions, new deployments, standard file extensions and naming conventions, survey and design deliverables, plans production, and recommendations for model-based design. In addition, there are multiple appendices which elaborate on topics covered throughout this document.

Although the ***Requirements for Model-Centric Design*** document does not replace the need for training, it is meant to document standard digital design procedures developed by TDOT and should be referenced throughout each project. This document will be updated on a yearly basis and the revisions will be outlined in the **Model Revision History** section located near the end of the document.

General Background

TDOT is currently using MicroStation V8i (SELECTseries2) and GEOPAK for transportation design and project plans development. Beginning in **July 2021**, the Department will migrate to Bentley's OpenRoads Designer (ORD) CONNECT Edition software for all new surveys, which seamlessly blends engineering workflows for plan, profile, and cross-sections with 3D parametric modeling in order to ultimately enable model-centric design deliverables. ORD is a comprehensive and fully functioned detailed design application for surveying, drainage, subsurface utilities, and roadway design that supersedes all capabilities previously delivered through InRoads, GEOPAK, MX and PowerCivil.[1]

Currently, the workflow for project design development includes transforming base map data (e.g., surface models, aerial imagery, planimetrics, and other existing conditions data) into a CAD environment from which the design is based. The designer then uses GEOPAK to incorporate engineering decisions into the CAD environment that builds separate plan, profile, and cross-section sheets conveying the overall design intent. Conversely, ORD allows graphics, geometry, and surface data to be stored in a single format (e.g. DGN), therefore, streamlining the workflow and interface. Ultimately, this feature enables designers to build a comprehensive **3D** model which showcases a collaborative design effort and more clearly conveys the design intent.

There are numerous expected benefits to transitioning from the current platform to ORD, including:

- Use of digital data throughout the life of a project.
- Improved execution of the designer's design intent and continuity across TDOT regions.
- Ability to deliver a higher quality product to the contractor with a more accurate project footprint related to earthwork and construction limits.
    - This includes **Automated Machine Guidance** (AMG) which uses data from the project's 3D model to guide construction equipment during earthwork and paving operations.
- Creation of a better visualization tool for engineering analysis and coordination with other design disciplines.

With the initial rollout of the new software, project deliverables will continue to be in the form of a **sealed PDF plan set**, which represents the contractual legal document. The **3D model** will serve as **supplemental** data for the time being. At a later date, the Department will examine full digital delivery, also referenced more commonly as Electronic Engineering Data (EED), which can be consumed further downstream in Asset Management and Maintenance.

[1] "OpenRoads - Civil Design Software for Road Networks," *Bentley*, https://www.bentley.com/en/products/brands/openroads, Accessed 14 Jan, 2021

Terminology

While some terms are previously known, ORD does introduce new terms and processes, some of which are listed below. Knowing this terminology will allow designers to have a better understanding of the new software and application of it. **Note:** These terms may not be utilized within this document but are referenced in the ORD training manuals.

- **Configuration:** TDOT specific files that control where the software looks for different workspace components.
- **Corridor:** Objects that make up the proposed roadway, such as template drops, point controls, end condition exceptions, parametric constraints, etc.
- **Geometry:** Horizontal and vertical alignments.
- **Intelligent Data:** 2D/3D data that the software can automatically access across model spaces to link or affect another model space within that file or in other files. Fundamentally this results in a cause and effect relationship across model spaces. This includes geometries, corridor elements, annotation etc.
- **Model Annotation:** This is how ORD handles “intelligent” annotation, such as geometry stationing and bearings/distances, survey elements like pipes, buildings and trees, as well as profile/cross section elevations, dimensions and volumes.
- **Terrain:** Surface model that represents existing ground, the proposed design or other surfaces that are referred to as digital terrain models (DTMs).
- **Unintelligent Data:** 2D data that the software cannot automatically access across model spaces and has no inherit cause and effect relationship across model spaces. This data is often referred to as “Microstation” as it utilizes the base drafting technology that underpins the ORD software.
- **Workflow:** Allows the applicable tools to display in a project specific order across the Ribbon.
- **Workset:** A project folder where the user will store all project files.
- **Workspace:** A collection of TDOT standard settings that control how the software works.

Conversion of Existing Projects (GEOPAK) to ORD CONNECT

Once ORD CONNECT is deployed statewide in July 2021, all new projects will begin with survey data prepared per ORD workflows, as outlined within the Survey (ORD) training manual. Existing projects will be analyzed on a project-by-project basis to determine if a project should be converted to ORD. In-house designers and external consultants should coordinate with their applicable TDOT design manager to determine if a project should be converted or not.

To guide design managers and decision-makers, conversion graphics have been developed and are located in **Appendix A. Conversion Guidance**. In general, if a project is in the preliminary design phase, there may be added value to convert it from SS2 to ORD. Conversely if a project has been funded for construction, it is best suited to progress forward as-is in SS2. Design managers and applicable staff should reference the graphic located in **Appendix A.2. ROW ORD Conversion Decision-Making Flow Chart** if a project is within the **Right-of-Way (ROW) phase**. This area of project design development tends to have more variables and elements to consider with regards to conversion.

In addition to the conversion guidance figures outlined in Appendix A, designers/design managers should consider the following criteria during the conversion evaluation process:

- How much effort has been put into developing plan sheets and cross sections?
- How often are designers making changes to the design and revising plan sheets?
- How often are designers updating cross-sections?
- What is the timeline of the project?

Design managers should reference and complete the **ORD Conversion Decision-Making Form** which accompanies the above referenced conversion graphic(s).

SS2 Survey Implementation

A configuration zip file has been developed for utilizing a SS2 survey in an ORD project, in order to visualize all 2D survey elements correctly. This resource must be applied to **any and all ORD projects that have an SS2 survey**; otherwise, graphics will not display properly**.** This SS2 survey implementation resource can be found via the TDOT ORD webpage. (Reference **Appendix B. SS2 Survey Implementation into ORD** for directions on how to incorporate this resource on applicable projects.)

Deployment of ORD Software Updates

Bentley will release annual *major* software releases, at a minimum, for ORD CONNECT Edition. There likely will be other *minor* intermittent releases throughout a given year. **TDOT will evaluate each release to determine whether there is value and/or a need to upgrade.** The update will be a coordinated effort between the Department's Information Technology (IT) Division and the Roadway Design Division in order to develop and prepare a deployment package. Below are a few important questions that TDOT will consider when evaluating each Bentley release:

- Does the release fix issues that are hindering the design process and/or design projects?

- Does TDOT CADD Support have adequate time to thoroughly test each release? Each release should be tested using a consistent check list and data set to confirm

whether previous issues have been resolved. If issues still persist, new defects would need to be reported to Bentley. (With each new release, Bentley provides a summary of updates.[2])

- Does TDOT's IT Division have the resources to deploy a package before the next release comes out?
- Does the release require any updates to the training materials? If so, what is the level of effort to update and distribute the new training material?

Once these questions have been evaluated, TDOT can then make an educated decision on whether to deploy the release. Regardless of how many Bentley releases there are each year, TDOT will update the ORD CONNECT Edition software on an annual basis, at a minimum. A consistent annual deployment not only allows the CADD and IT staff to plan for the deployment, but it also allows TDOT project development staff and consultants to plan accordingly for projects.

Workspace Structure

A **workspace** is a collection of standard settings that control how the ORD software works. A single TDOT workspace (**TDOT_Standards**) has been created with a layered structure and includes resources, standards, and tools necessary for designing projects in accordance with TDOT standards. The default Bentley ORD installation process puts the workspace configuration files on the **C:** drive. The following sections provide more details on the layered structure.

Organization-Civil: This level represents the Bentley-delivered base standards and allows the flexibility to set up a layered TDOT-specific workspace environment within, which includes the TDOT standards, so that they are applied to all ORD projects.

Workspace: This level allows an organization to set up specific standards for different functional units or disciplines. Within the **TDOT_Standards** ORD workspace, there are components setup for the following transportation disciplines: Survey, Roadway, Drainage (SUDA), Structures, and STID.

There are two (2) options for installing and running the workspace: local user hard drive (e.g. C:\ drive) or specified network location. For internal purposes, the TDOT workspace will be installed to each user's local hard drive. For TDOT designers and staff, TDOT IT will install the workspace for the applicable users. However, for external users, **Appendix C. Workspace Installation Guidance (External Users)** outlines installation directions.

Workset: This level is directly tied to sheet indexing and also allows TDOT to specify standards for a project that supplements the primary Workspace and/or Organizational

[2] "OpenRoads Designer Readme – What's New," *Bentley,* https://docs.bentley.com/LiveContent/web/OpenRoads%20Designer%20Readme-v12/en/GUID-9CA386EA-84C2-4D4B-A6D9-8719E410B13F.html, Accessed 29 Jan 2021

standards. The workset folders are equivalent to project folders. Five (5) standard workset templates have been developed and are included in the TDOT workspace:

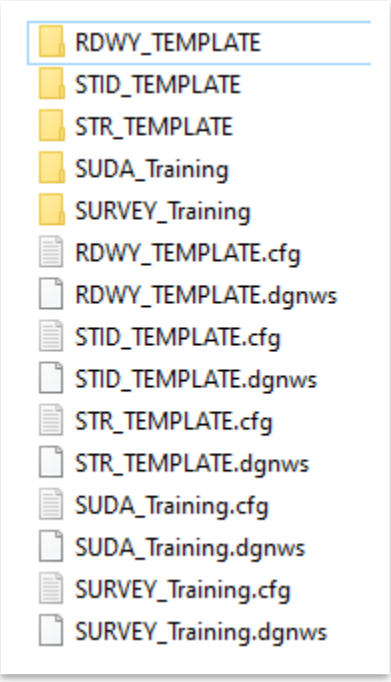
- **RDWY_TEMPLATE:** This workset template should be used by the **Survey**, **Design** and **Operations** staff as a basis for all new roadway design project worksets.
- **STID_TEMPLATE:** This workset template should be used by the **Strategic Transportation Investements Division (STID)** staff as a basis for all new STID project worksets.
- **STR_TEMPLATE:** This workset template should be used by the **Structures** Division as a basis for all new structures project worksets.
- **SUDA_Training:** This is a **training** workset template and is intended for users focusing on hydraulic analysis and drainage calculations for proposed storm drain networks (e.g. drainage and utility modeling workflow in ORD).
    - For non-training purposes, users would then traditionally use the **RDWY_TEMPLATE.**
- **SURVEY_Training:** This is a **training** workset template and is intended for Survey staff.
    - For non-training purposes, users would then traditionally use the **RDWY_TEMPLATE.**

When a project workset is created, a workset folder and two corresponding files (.cfg and .dgnws) are created in the Bentley default location: **C:\ProgramData\Bentley\Open Roads Designer CE\Configuration\WorkSpaces\TDOT_Standards\WorkSets** (Figure 1 on the following page). Within the workset folder is a series of subfolders that are automatically created and are initially empty. As project data develops, the folders are populated with DGN files, spreadsheets, databases, and other files.

Similar to the workspace setup, workset folders may be placed either locally on the user's C:/ drive or in a standard network location. For the initial rollout of the software and for internal training purposes, TDOT will install the workset to each user's local hard drive. **Once internal ORD training has concluded, the Department will modify the workset location to include both a local hard drive and a unified network configuration which aligns with current practices within the Department.** In the future, the workset location will have to be modified once the Department transitions to Bentley's ProjectWise:

- Headquarters staff – Local hard drive
- Regional staff – Unified network configuration
    - The proposed ORD shared drive path is the following: **\\TDOT0#NAS002.tdot.state.tn.us\0#Shared\ORD\Projects**

FIGURE 1. WORKSET FILE AND FOLDER STRUCTURE



2D vs. 3D

As noted in the **TDOT ORD File Naming Convention Standards** document (discussed in the following section,) there is guidance on whether to utilize a 2D or 3D seed file when creating project files. (A seed file is a term for a file template, ensuring that newly created files have default parameters, such as working units, color table, views, etc that are aligned with TDOT Standards.) In ORD, it is very important to be cognizant of what is placed in a 2D model vs a 3D model; therefore, it is important for users to understand the difference and interaction of these files.

- **2D Seed File:** Contains both a 2D model and a 3D model by default. This is required to implement new 3D linestyles in ORD. When a 2D seed is required, work should be done in the 2D model rather than the 3D model. The 3D model within the 2D seed is considered a visualization tool **only**. Designers affect the 3D model by manipulating the 2D model space. ORD is intelligent enough to interface between both models seamlessly while inside the 2D model.
- **3D Seed File:** Contains only a 3D model by default. When a 3D seed is required, work should be done in the 3D model. For these files, the 3D model is not just a visualization and contains survey data or a digital terrain model.

Imported survey data should be placed in a 3D file. By doing this, it facilitates the creation and placement of terrain models, drainage data, and other survey features where the elevation is critical. However, certain aspects of a survey (e.g. alignments) require elements to be placed in a 2D seed model and then have a profile assigned. In general,

once a profile has been assigned to a 2D element, a 3D representation is then drawn in the 3D model that utilizes the assigned profile to give this element elevation data. This separates the 2D geometric elements from their 3D representation, which is imperative.

The Survey (ORD) training manual directs the designer on when to use a 2D or 3D seed file for survey file creation. For reference, see **Appendix D. Survey Deliverables Process** for this information. To summarize, the four (4) survey file deliverables will utilize both 2D and 3D seed files as follows:

1. **Model.dgn** file created in a **3D seed** which contains 2D planimetric graphics and point data imported from the original Field Book(s).
2. **Terrain.dgn** file created in a **3D seed** which contains the existing DTM features (e.g. contours, triangles, etc).
3. **Alignment.dgn** file created in a **2D seed** which contains the survey preliminary centerline (plan and profile) and projected utilities (profile).
4. **Utility.dgn** file created in a **2D seed** which contains the existing drainage and utility model (plan).

An **ORD Survey Data Checklist** has been developed and should be completed by the survey team once all data has been processed and deliverables have been developed – in preparation to submit all survey files to design.

Furthermore, most Design files utilize a 2D seed file, as noted in the inventory of project files listed in the **TDOT ORD File Naming Convention Standards** document (except for proposed terrain files.) Horizontal geometry must **always** be stored in 2D models, which provides several advantages:

- The feature definitions allow for different 2D and 3D representations. The user can consider the 2D as the planimetric design plus annotation and the 3D as the visualization model.
- With separated 2D information, rotated 3D views will only show elements with the elevation assigned and no information will show at elevation zero.
- Selection of elements is simplified when separated into 2D and 3D storage models. References can be turned off or left on (with snaps turned off).
- In addition, digital terrain models (existing or proposed) are naturally 3D elements and thus 3D models must be used.

Standard File Naming

Similar to TDOT's CADD V8 standards manual, a **TDOT ORD File Naming Convention Standards** document has been developed in order to provide guidance and consistency for all project files developed in ORD. Some projects will not utilize all the files listed in this document. Conversely, some projects may require additional files compared to what is listed, and designers should follow the naming convention established in this document

to develop an appropriate file name. This document aligns with new state project number formatting guidance released in April 2021 and contains the following sections:

- Standard file extensions
- Standard **survey** workflow and file standardization, including:
  - Survey project file naming convention
  - Survey project deliverables
- Standard **design** workflow and file standardization, including:
  - Design project file naming convention
  - Design project deliverables

Within the appendix of the **TDOT ORD File Naming Convention Standards** is an inventory of project files, broken down into the following project development phases:

- Planning (e.g. Strategic Transportation Investments Division)
- Survey and Design

Creating a Set of Plans in ORD

There are six (6) TDOT-specific ORD training manuals with embedded how-to videos that will become available in 2021 and 2022. These training materials focus on a specific functional area of project development. Holistically, the manuals cover modeling capabilities and the “how-to” of operating the new software.

The following section is intended to provide guidance on specific means, methods, and best practices to successfully create a TDOT-specific set of plans. It should be noted that the “look and feel” of plans produced in ORD will differ compared to plans generated via GEOPAK. Although most alterations are minor, designers, design managers, and reviewers should be aware of the new look that TDOT plans will inherit. As the new standardization of TDOT plans production evolves within ORD, the Department will educate and raise awareness of these “new standards” to both internal staff and external users.

Lastly, the **TDOT ORD File Naming Convention Standards** document should serve as a resource for plans production. It is meant to work in conjunction with this section to provide the knowledge that designers need to successfully create a TDOT set of plans, implementing the revised TDOT CADD standards for file naming and structure, and the new workflows introduced within ORD.

Digital Files

All digital ORD file names should follow the preset project file naming convention standards. For STID, the file naming convention begins with the project’s PIN number. For Survey and Design, the naming convention begins with the 2-digit county number and

aligns with the new state project number formatting guidance. A few file name examples are listed below for quick reference:

- 123456.00-STID-Proposed.dgn
- 58S028-01-SUR-Model.dgn
- 58S028-DES-Corridor.dgn
- 58S028-SHT-EPSC-III.dgn

[Moving forward within the remaining sections, there will be references to file names. The "**project name**" portion of the file name (58S028 in the above examples) will be removed in order to reduce redundancy.]

Sheet Files

Sheet files and plans production in ORD have changed significantly. Designers will no longer create individual ".sht" files for each sheet. Also, printing is no longer done from the design model space. In order to fully capitalize on ORD's sheet indexing and linked annotation, designers will now have a **Drawing Model** space and a **Sheet Model** space.

- **Drawing Model:** A model space with a grey background that has the design files referenced and clipped by the named boundary. This is essentially an isolation of the applicable sheet in a design model. Changes can be made in this model space, and in some occasions (e.g. profile and cross sections), this is the location where additional annotation is added.
- **Sheet Model:** A model space with a white background that has a default paper size and sheet border loaded from the selected sheet seed. This model space is where the "sheet" resides. Only the sheet border elements (e.g. the sheet title text) should be added/edited in this model space. All other adjustments should either be made in the design model for plan view sheets or the drawing model for profile and cross section sheets.

Multiple Drawing Models and Sheet Models will be grouped together in like files. For example, all the ROW Details sheets will be in a single file. To indicate whether a file contains a sheet or sheets, the designation "**SHT**" will replace "DES" in the file name. Therefore, an example of this naming convention would be "**-SHT-ROW Details.dgn**"

These "SHT" files will largely serve as a "Motif" file. The required reference files should be attached to the design model space, and then the applicable level filter applied to override any level display variance from the reference files. The drawing models and sheet models are then created from this design model space. **Designers should not control the level display of references within the sheet model.** Due to ORD instability it may be necessary for designers to review and control the level display of the sheet text (i.e. DES – Sheet Plot Shape, DES – Sheet – Revision Text, etc.) within the sheet model to ensure consistent level display across the plan sheet package with respect to the sheet border.

Design File Sequence Overview

Every design is different, yet every project follows the same file creation sequence to create an overall set of plans. Designers should create the design files per the overarching sequence shown below.

1. Create Proposed Horizontal and Vertical Alignments
2. Create the Plan View Named Boundaries
3. Create the Core Sheet Files
    a. Sheets file for Present Layouts
    b. Sheets file(s) for Proposed Profiles
4. Corridor Modeling and Design
    a. Including but not limited to: Corridors, Supereleveation, Drainage Modeling, Earthwork, ROW Details, Signing and Marking, etc.
5. Incorporate Design into the Core Sheets
6. Create the Secondary Sheet Files
    a. Including but not limited to: Title Sheets, General Notes, Property Maps, Cross Sections, etc.
7. Create a PDF Plan Set
8. Design Stage Progression & Revisions

Survey Files

As noted in previous sections, survey staff is required to provide four (4) ORD deliverables:

1. **SUR-Model.dgn**
    a. Traditional survey file
2. **SUR-Terrain.dgn**
    a. Existing terrain DTM
3. **SUR-Alignment.dgn**
    a. Existing centerlines
4. **SUR-Utility.dgn**
    a. Existing 3D utilities and drainage structures

Throughout the life of a project, designers are going to have to adjust the survey file in order to make corrections, such as text overlaps or text rotation, once the plan sheets are laid out. Before making any of these changes, designers should save the original version of all survey files in a folder marked with the original date received.

It is recommended to attach the other three (3) survey deliverables (SUR_Terrain, SUR-Alignments, SUR-Utility) to the overall **SUR-Model.dgn** file. This ensures that all the

survey data can be accessed by referencing a single file. When referencing the “survey file,” designers should reference the SUR-Model.dgn file and turn on “Live Nesting” in order to view all the survey content comprehensively.

Step 1: Proposed Alignments

Starting a project in ORD requires some initial work at the workset level. This information is covered in the TDOT (ORD) Fundamentals training manual and should be strictly adhered to before beginning any design work.

All horizontal and vertical alignments for all roadways in the proposed design should be saved in a single alignment file. If the job is large and/or complex and the designer feels it is warranted, then each proposed alignment should have its own file with a “-Roadway Name” to define which alignment is in this file. An example of this is: DES-Alignments-SR1.dgn

All begin/end project labels, intersection labels, stationing, and curve text should be placed in a separate file named “DES-Alignments-Text”. This file should have a minimum of two (2) design model spaces within it – one (1) for 50 scale annotation and one (1) for 200 scale annotation. In each model space, all DES-Alignments files should be referenced so that they all can be annotated in a single file.

Both the DES-Alignments and DES-Alignments-Text files should have the SUR-Model referenced with “Live Nesting” on at a minimum. This will allow designers to set the existing terrain to active when designing vertical alignments in the alignments file and to see text overlaps in the text file.

Lastly, designers will create the Alignments Master file. This file should be named “DES-Alignments-Master.dgn” and will contain the references of all alignment files and the alignment text file. This file should have a minimum of two (2) design model spaces within it – one (1) with the 50 scale annotation and one with the 200 scale annotation. When referencing the “alignments file,” designers should reference the DES-Alignments-Master file and turn “Live Nesting” on in order to display the roadway alignments and alignments annotation utilizing a single reference file.

When referencing a “Master” file, designers should **always** have “Live Nesting” turned **on** because a master file should not contain any active elements but rather bring together all sub files of that overall file category. Whereas, the individual files that make up a “Master” file should have “Live Nesting” turned **off**.

Step 2: Plan View Named Boundaries

In ORD, named boundaries take the place of what was traditionally referred to as “Sheet Layouts” or “Clip Shapes” and enable the creation of plan, profile, and cross section sheets.

For plan views, designers should create a new file called “DES-NB-Plan” and reference in the Alignments Master file with “Live Nesting” turned on.

Designers should then layout the plan sheets utilizing the skills taught in the Roadway Design I (ORD) training manual. During the plan sheet layout, **designers should set the “Boundary Chords” value to 1.** The boundary chord control is essentially the number of vertices along the top and bottom of the named boundary (e.g. a chord of 10 would mean the boundary would more accurately curve along the alignment in a curved section because it has more pivot points so to speak. However, plan sheets are rectangular rather than curved, so the boundaries need to reflect that for the sheet views to be placed correctly without the need for adjustments.

Designers should not select “Create Drawing” when creating the named boundaries within the named boundaries file. Designers will create the drawings (e.g. sheets) after the fact inside the applicable motif files and not in the named boundaries file.

If a project requires adjustments to the named boundaries drawn by the software, like insets, matchlines on the top or bottom of mainline sheets, or any other adjustment, then designers should not make those adjustments at this time. These adjustments must be made after creating the present layout sheets for the first time. This will ensure that the view frames are correctly rotated and positioned on the sheets. Instead, it is recommended that designers set the active level to “DES - SCRATCH - User 1” and utilize MicroStation tools to draw linear elements to represent the intended adjustments. **Do not make the adjustments at this time**. Once the present layout sheets have been created for the first time, designers can go back into the “DES-NB-Plan” file and make the intended adjustments to the named boundaries The adjustments should be made using the guiding elements placed on the DES - SCATCH - User 1. It is likely that a designer will need to add vertices to the named boundaries to make their adjustments utilizing the “Insert Vertex” tool.

Profile named boundaries must be placed in the file that the sheets are created in. Therefore, there will be no “DES-NB-Profile.dgn” file. These boundaries will instead be created in the sheet file called “SHT-Proposed Profiles.dgn”.

Likewise, cross section named boundaries must be placed in the file that the sheets are created in. Therefore, there will be no “DES-NB-XS.dgn” file. These boundaries will be created in the sheet file called “SHT-XS-Roadway.dgn”. Additional insight on the setup and purpose of sheet files will be covered in the “Core Sheet Files & Secondary Sheet Files” sections of this document.

Step 3: Core Sheet Files

Plan Views

The first plan sheets a designer should create are the present layouts. To do this, designers should create a file named “-SHT-Present Layouts.dgn”. At a minimum,

designers should reference the DES-Alignments-Master, SUR-Model, and DES-NB-Plan files. The Master alignments file should have “Live Nesting” on. The designer should then apply the “Sheets-Present Layout” level filter to the design model space. Then, designers will open the Named Boundaries toolbox and locate their plan view named boundary group. Select all the plan sheets, right click, and select “create plan drawing”. This will create the sheet model spaces and sheet layouts for all the sheets in the selection. These sheets are now all stored in this “SHT” file as intended.

Note: *Drawing model and Sheet model names matter only to the designer. They do not affect the annotation of the sheet because it is pulling the sheet number assigned in the ORD index. It is recommended that designers take time to name their sheet models and sheet layouts appropriately, so they can be easily identifiable. Examples of suggested naming schemes are 4, 4 [sheet], 5, 5 [sheet] or Plan 1, Plan 1 [sheet], Plan 2, Plan 2 [sheet].*

Once these sheets have been created, it is now ok to go back to the “DES-NB-Plan.dgn” file to make any named boundary adjustments that are necessary for that project. Making adjustments after the first set of plan sheets are created ensures that the plan sheets for the project are rotated and placed correctly in the sheet layouts without the need for adjustments.

In the “SHT-Present Layouts.dgn” file, designers should open the sheet index for editing. Open the Models window and drag all the “[sheet]” models into the applicable sheet index folder. For present layout sheets, the folder is called “Present Layout(s)”. Once the sheet layouts are associated with this folder, they will be automatically numbered according to TDOT standards starting with number 4. To synchronize the matchline text and the sheet numbers with the number automatically assigned in the ORD index, designers should open a drawing model for one of the sheets and use the “Remove Model Annotations” tool and remove the annotations for all models. Then use the “Annotate Model” tool to reannotate all drawing models with correct sheet numbering. All sheets should be reviewed to ensure the correct title, number, and levels are shown.

Note: *Changing sheet model names after linking the models to the index will drop the link. The models will then have to be re-linked to the ORD index.*

Profile Views

First, designers need to create the proposed profile sheets file and name it “SHT-Proposed Profile.dgn”. In this file, designers should reference the Master Alignments file at a minimum. It is recommended to create the mainline profile sheets first and then the side road profile sheets. Private drive profile sheets should be created as part of the **Secondary Sheet Files** (Step 6 below.) Designers will open the mainline profile view and create named boundaries.

The stationing and length of the profile sheets should match that of the plan views that they accompany. Designers can select “create drawings” before exiting the named

boundary tool, if desired, to create the drawing and sheet models in one click. Once the sheets are created, the vertical alignments will be annotated automatically.

All profile annotation must occur in the profile **drawing** models. Profile Views in the design model are dynamic and cannot be annotated. Designers should now place all project information annotation (begin/end const., intersection callouts, etc.) manually in the applicable drawing models.

Note: *This workflow addresses the initial sheet creation. See Step 6 for integration of proposed drainage and existing utilities on profile views.*

Side road profiles will fall into two (2) categories:

1. Significant side road profiles that take up an entire profile sheet(s).
2. Minor side road profiles that take up less than one sheet and could feasibly be combined with other side road profiles onto a single sheet.

For #1, follow the above workflow to create the proposed side road profile sheets. For #2, designers should refer to the Profile Views section of Step 6 to place multiple profiles on a single sheet in ORD.

Step 4: Corridor Modeling and Design

Proposed Corridors

Each roadway in the design should have a separate corridor file and separate CTRL files. The CTRL files should be named “DES-Corridor-CTRL-Road Name”. These files are allocated for designers who chose to control a corridor or parts of a corridor based on linear elements.

All proposed plan view text, excluding project information text that is included in the DES-Alignments-Text file, should be placed in a file called “DES-Corridor-Text”. At a minimum, this file should have all proposed corridors and the plan view named boundary file referenced in so that all text can be rotated correctly.

A Corridor Master file named “DES-Corridor-Master” should be used to bring together all corridors, proposed text, and proposed design elements, including bridges, drainage structures, pavement marking etc., into a single file that can be referenced. This file takes the place of the traditional “proposed” file.

Superelevation

Each roadway in the design should have a separate superelevation file. After creating all the superelevation files for each roadway, designers should create a superelevation Master file named “DES-Superelevation-Master” that contains all the superelevation files as references. Designers, when referencing the “superelevation” file, should reference the DES-Superelevation-Master file and turn “Live Nesting” on.

Superelevation should be assigned to corridors in each of their respective files and not in the Corridor Master file.

Civil Cells

TDOT utilizes a library of custom-built civil cells to make complex modeling situations easier and faster for the average user. These cells also help bring consistency across the regions so that TDOT designs are the same throughout the state and meet TDOT standards. Complex modeling situations such as driveways, curb-ramps, and intersections are all intended to use the applicable TDOT civil cell. However, civil cells are limited and not all civil cells will work in all scenarios, and in some cases, designers will have to utilize the provided TDOT civil cell as a starting place to model the scenario manually.

Civil cells must be placed in the corridor model that they are clipping. For example, if placing an intersection civil cell where a side road is intersecting the mainline, it must be placed in the mainline corridor file and not the intersecting roadways corridor. The intersecting roadways corridor should then start where the intersection civil cell stops on the side road.

Drainage

The Subsurface Utility Design and Analysis (SUDA) (ORD) training manual provides the information and skills needed to design a drainage model in ORD. All the hydraulic calculations as well as proposed and existing structures to remain should be placed in the file named “DES-Drainage-Hydraulic Model.dgn”. The hydraulic analysis for box culverts and slab bridges will also be in the previously mentioned file. However, the 3D model for these structures should be in the file “DES-Drainage-Structures Model.dgn”. This is required because the 3D modeling capabilities of these structures within the SUDA tools is not comprehensive enough for the 3D model of these structures. Likewise, if any modeling is required for stream relocations, the model will also be done in a separate file named “DES-Drainage-Stream Relocation Model.dgn”. Refer to the Roadway Design II (ORD) training manual for the skills required to model these items.

Profile drainage design and annotation should also be done in the “DES-Hydraulic-Model.dgn” file. Unfortunately, profile views or named boundaries cannot be referenced into each other at this time. Because of that, be careful when preparing the profile view named boundaries of drainage systems that are parallel to a roadway alignment, and make sure they mirror those created in the core sheet files. When designers are creating named boundaries, they should select “create drawings” before exiting the named boundary tool to create the drawing and sheet models in one click. The **drawing models** created during this procedure are going to be referenced into the “SHT-Proposed Profile.dgn” file in order to get the drainage annotation onto the proposed profile sheets. The **sheet models** created during this procedure should now be deleted. **Do not** delete the drawing models. All existing and proposed drainage annotation marked “to remain”

should be located in the applicable drawing models of the “DES-Drainage-Hydraulic Model.dgn”.

Earthwork

Earthwork workflows will evolve as the ORD software continues to develop and improve. For now, the series of steps designers will need to perform in order to calculate earthwork is explained below. First, designers will need to make an earthwork file for each corridor. These files will align with the following naming convention: “DES-Earthwork-Road Name.” In each file, designers will run the earthwork workflow taught in the Roadway Design II (ORD) training manual. Earthwork in ORD runs a **volumetric** method that calculates the true cut-fill volumes of the model. This allows a more accurate calculation but also means there is a lot more processing that needs to be done. Separating the corridor calculations goes a long way to making this process manageable. All the separate corridor earthwork calculations and shapes should be brought into a “Master” file to bring together all the data across the project into a single file. This file should be called “DES-Earthwork-Master.dgn.” At a later date, these design digital files will be delivered to contractors but marked as **for information only.**

For the earthwork calculations that are shown on the plans, the **average end area** method will be used. To get the average end area calculations to annotate on the cross section sheets, the earthwork must be re-run in the file that the cross section sheets are created in. The earthwork that is run in these files is for the average end area annotation on cross section sheets only. In the future, designers should be prepared to deliver the digital individual “DES-Earthwork” files along with the Master Earthwork file to the contractor.

Proposed Terrains

In ORD, designers are required to deliver the design proposed-finish-grade (PFG) at a minimum. This should be done for each individual corridor and should be called “DES-Terrain-PFG-Road Name”. Designers are also required to create a design PFG Master terrain that is either a complex terrain from the individual corridor terrains created, or a single terrain created from the “DES-Corridor-Master” file.

Note: *Optionally, designers may choose to provide the design grading surface (GS), proposed paving surface (PS), and/or the proposed roadway surface (RS) for the proposed model. These other surfaces can provide additional value to the contractor for automated machine guidance. These are not required by TDOT as deliverables at this time unless otherwise stated in the contract for the project.*

ROW Details

ROW details are mostly comprised of annotation, labeling, and patterning. Refer to the Fundamentals (ORD) training manual and the Roadway Design I (ORD) training manual for specific tools and skills needed to generate these details. In general, designers will

need to select the appropriate element template before selecting a label or pattern. The element templates will have the correct level symbology or pattern associated with it.

In order to get existing or proposed ROW onto the XS sheets, designers need to assign the existing ground profile as the active profile to the ROW linework. For proposed ROW lines, this can be done in the “DES-ROW.dgn” file. For existing ROW, this can either be done in the “SUR-Model.dgn” file or copies can be made of the required linework and done in the “DES-ROW.dgn” file. As long as the ROW linework has the existing ground profile assigned as the active profile before creating cross section sheets, the annotation will automatically place when the sheets are created.

Step 5: Incorporate Design into Core Sheets

Plan Views

The core sheets should be created before the bulk of design happens. Therefore, designers will need to reconcile design elements created after the core sheets were developed into the core sheet files. For plan views, this only requires the addition of any reference that contains elements that need to be shown. For example, in the present layout, the “DES-ROW.dgn” file will need to be referenced into the “SHT-Present Layouts.dgn” file for it to be displayed on the present layouts. After referencing new files into the design model, designers should always re-apply the applicable level filter to the design model space.

Profile Views

Profile view sheets are more labor intensive than plan view sheets. Typical data that may need to be shown on the proposed profile sheets include existing utilities and proposed drainage. Each of these sets of information requires a separate workflow for how to get the information displayed on the proposed profile sheets.

First, the proposed drainage information will be addressed. To get the proposed drainage design and annotation into the profile, designers must first open the “SHT-Proposed Profiles.dgn” file. Then, the designer must open the first drawing model space that correlates to the profile of the first plan sheet in the design (e.g. sheet 4C). Now designers can reference the “DES-Drainage-Hydraulic Model.dgn” file into this drawing model. Change the model space of the reference to the matching drawing space in the “DES-Drainage-Hydraulic Model.dgn” file. The profile drawing model from the “DES-Drainage-Hydraulic Model.dgn” file should automatically be aligned with the active model in the “SHT-Proposed Profiles.dgn” file. If it is not, move the reference to the correct location. Repeat this method for all profile sheets that will show proposed drainage systems.

To get the existing utility information on the proposed profile, there are several factors at play. If the proposed alignment is the same as the surveyed alignment, then designers would open the DES-Alignments.dgn file (profile drawing model) and reference in the SUR-Alignments file (profile drawing model), which has the existing utilities already

projected onto the CL profile. Then, turn off the unnecessary levels in the reference (e.g. DES – PRO – Proposed Text).

If the proposed alignment changes from the surveyed alignment, then the designers would need to re-project the existing utilities in the DES-Alignments.dgn file. Attach the SUR-Model.dgn and re-project the non-modeled existing linear utilities (e.g. water line) and attach the SUR-Utility.dgn file and re-project the modeled existing linear utilities (e.g. SA line, drainage pipe). For crossing utilities (also in the SUR-Utility.dgn file), the "reprojection" is done via the Create 3d Cut tool within the dynamic profile model in the DES-Alignment.dgn file. If a 3d Cut boundary has previously been placed, you would simply refresh the 3d Cut and the existing utilities would appear.

Step 6: Secondary Sheet Files

Plan Views

Secondary plan view sheet files can be created in the order a designer sees fit. The total number and what is required is determined by the phase of the project. However, the steps outlined below are the general process required to create any plan view sheet that matches the scale of the present layout sheets (typically 50 scale):

1. In windows explorer outside the ORD software, copy the "SHT-Present Layouts.dgn" file. Then, rename it to the applicable set of plan view sheets. (For example, the ROW Details sheets.) This copied file would now be named "SHT-ROW Details." Creating the rest of the sheets using the present layout sheets file as a "seed" ensures that all view frames, matchlines, and north arrows are consistently placed across the plan set. This is especially important if any named boundary adjustments have been made.
2. Open the new file. In the drawing model space, add or delete any references that are needed or not needed. Set the level filter for all references to the appropriate name – in this case it would be "Sheets – ROW Details".
3. Adjust the names of the drawing and sheet models to maintain easy identifiable naming when viewed in the ORD index.
4. Open the sheet index for editing in ORD. Then, open the models window and drag all the "[sheet]" model spaces into the applicable folder of the index. This will automatically assign sheet numbers based on TDOT standards.
    a. For sheets which are not alphanumeric off the present layout (e.g. EPSC sheets), designers will need to calculate how many total sheets will be ahead of the first sheet in the folder and manually input the first number in the folder properties. After adjusting the first sheet number in a folder, the other sheet numbers will auto-increment off that number.
5. With the sheet models associated with the correct folder in the index and the correct numbers assigned, designers can correct the matchline text by removing

the plan annotation in the drawing models and then re-annotating the drawing models with the correct information.

6. Review to ensure the correct title, number, and levels are shown on each sheet.

For 200 scale sheets or any other scale that is not equal to that of the present layouts, designers should follow these steps:

1. Open the file “DES-NB-Plan.dgn”. Open the model space manager and create a new model spaced called “200 scale”.
2. Set the drawing space scale to 1”=200.’
3. Reference in the Master Alignments file.
4. Create named boundaries as desired. Do not make any adjustments to the named boundaries at this time.
5. Create the desired sheet file. For example, Property Maps would be “SHT-Property Map.dgn.”
6. Reference in the required files and set the level filter for all references to the appropriate name. Ensure that the “DES-NB-Plan.dgn” is referenced and set to the 200 scale model space.
7. Open the Named Boundaries Toolbox, locate the plan view named boundary group. Select all the plan sheets, right click, and select “create plan drawing.”
8. Adjust the names of drawing models and sheet models to maintain easy identifiable naming when viewed in the ORD index.
9. Open the sheet index for editing in ORD. Open the models window and drag all the “[sheet]” model spaces into the applicable folder of the index. This will automatically assign sheet numbers based on the TDOT standard.
    a. For sheets which are not alphanumeric off the present layout (e.g. EPSC sheets), designers will need to calculate how many total sheets will be ahead of the first sheet in the folder and manually input the first number in the folder properties. After adjusting the first sheet number in a folder, the other sheet numbers will auto-increment off that number.
10. With the sheet models associated with the correct folder in the index and the correct numbers assigned, designers can correct the matchline text by removing the plan annotation in the drawing models and then re-annotating the drawing models with the correct information.
11. Review to ensure the correct title, number, and levels are shown on each sheet.

Once a set of sheets is created for that scale, it is recommended to copy that file and rename it to create the next set of sheets, as this will ensure consistency across the sheets and speed up the sheet creation process.

Note: *Line styles or annotation that originate in ORD will automatically scale based on the selected drawing scale. For line styles or annotation that originate outside of ORD (e.g. an SS2 survey/project that is being brought into or converted to ORD), designers*

will need to manually scale linework and annotation if the SS2 Survey Conversion Zip file has not been applied.

Profile Views

Placing multiple profiles on a single sheet is labor intensive in ORD. The software does not currently support an automatic way to place multiple profiles on a sheet at one time. Examples of profile sheets that might contain more than one profile are short side road profiles and private drive profiles. The steps below will go through the process as if designers are creating private drive profile sheets; however, the steps for both types of sheets are the same.

Designers should first open the “SHT-Proposed Profile.dgn” file. Then, designers should utilize the skills taught in the Roadway Design I (ORD) training manual to create profile named boundaries for a single driveway profile. Designers should select the drawing seed “Profile 50H 5V Scale” and shorten the length and available profile height to make a named boundary that provides enough room to capture all the information. For most driveways, the length would be 200 feet or less and 15-20 feet in height. Before accepting the named boundary, designers can select “create drawing” before exiting the named boundary tool, if desired, to create the drawing and sheet models in one click. After the models are created for a single driveway profile, designers should repeat the above steps for all private drive profiles.

With all private drive profile drawing models and sheets models created, designers can now work to consolidate private drives onto the minimum number of sheets. Every project is different, and the required number of sheets will vary accordingly. However, the general process is to take the first driveway profile drawing space created and reference in as many other driveway profile drawing models that will fit on one sheet. Designers should then work to label all the profiles on the sheet with the driveway type, side of the centerline, station, tract number, and alignment it is on. After labeling all the driveways in that drawing model, all the individual “[sheet]” models created that have a drawing model referenced into the first sheet can be deleted. For example, if driveways 1, 2 and 3 fit on one sheet together, then the sheet models for driveways 2 and 3 (not the drawing model that is being referenced) can be deleted from the model space organizer. After creating all the necessary sheets, designers should add the sheet models to the ORD Sheet Index and assign the correct starting sheet number, if required.

Cross Sections

Each individual roadway will have its own cross section sheet file. This is necessary for earthwork annotation to be correct. To start making cross section sheets, designers need to a create a file named “SHT-XS-Roadway.dgn.” At a minimum, this file should have the following files referenced in:

- DES-Alignments Master
- SUR-Model

- DES-Corridor-Road Name
- DES-ROW

The Master alignments and Survey model files should have “Live Nesting” on. If a roadway has multiple corridors that make it up (e.g. when there is a bridge), it is necessary to also reference those files. *Rule of thumb: If it does not show on that specific roadway’s cross section sheet, you do not want it referenced into the design model.*

After bringing in all the references, designers need to place cross section named boundaries in the design model. Refer to the Roadway Design I (ORD) training manual for how to do this. Before accepting the named boundary, designers can select “create drawing” before exiting the named boundary tool, if desired, to create the drawing and sheet models in one click. Once the drawing and sheet models are created, the cross sections will automatically be annotated.

Note: If a cross section is cutting a surface terrain with an associated surface template, the software is not capable of annotating cross slopes automatically at this time. This will occur most often when civil cells are placed in a model. This will also occur anywhere designers choose to model without linear templates. On most projects, this will result in only a few cross sections that will require some level of manual cross slope annotation. To determine cross slopes manually designers should follow these steps:

1. Use the “Line Between Points” tool to draw a line that represents the cross section cut line. (This is essentially a pattern line in GEOPAK).
2. Open the profile model of the line that was drawn.
3. Use the “Profile Intersection Point” tool to pull the intersection of all lines/breaklines that cross this element into the profile view.
4. Use the “Profile Line Between Points” tool to draw lines between the intersecting points. These lines will tell users what the cross slope is between lines/breaklines.
5. Repeat these steps for all cross sections that require manual cross slope annotation.
6. Open the cross section drawing models and annotate the cross slopes using the information gathered in step 4. It is recommended to copy an automatically annotated label and move it to the desired location to ensure uniform annotation.

If the project phase requires earthwork to be displayed on the cross sections, designers will need to follow these steps in the cross section sheet file where the annotation is to be placed:

1. Run the “Create cut and fill Volumes” tool to generate the earthwork shapes.
2. Run the “End Area Volumes Report.”
3. Open the drawing model space of the first cross section sheet.
4. Open the “Annotate Model” Tool and select the Annotation Group “XS EAV Table” and apply to all drawing models.

The earthwork cut and fill volumes should now be placed on the cross sections and populated with the end area volumes calculations created during the end area volumes report. Designers should now manually input the station ranges for each cross section sheet. Then, designers should add the sheet models to the ORD Sheet Index and assign the correct starting sheet number.

Culvert Sections

The SUDA (ORD) training manual covers how to create a culvert cross section. The linear elements required along with the drawing and sheet models should be stored in a file named "SHT-Culvert Sections.dgn." Designers should work in each culvert's drawing model to annotate and populate the culvert data table. Designers should attempt to consolidate the number of total culvert sections sheets required. To get more than one culvert section on a single sheet, designers should follow the methodology for placing multiple profiles on a single sheet outlined in the profile views section of **Step 6: Secondary Sheet Files**. After creating all the necessary sheets, designers should add the sheet models to the ORD Index and assign the correct starting sheet number.

Typical Sections

Typical sections in ORD should be drawn in the file named "SHT-Typical Sections.dgn" This file should be created from the "Roadway Typical Sections.dgn" seed file.

Note: This methodology is different than that in the TDOT Fundamentals Manual. The TDOT Fundamentals Manual will be revised to reflect this new methodology.

This seed file has representative sheet boundaries in the design model space for up-to 6 typical section sheets. It also has six (6) sheet models pre-clipped to speed up the production of typical section sheets. This should be enough typical section sheets for most projects. If more sheets are needed, designers can copy the representative sheet boundaries in the design model to give more drawing space and then copy a sheet model, adjust the reference location, and repeat to create as many sheets as needed. After creating all the necessary sheets, designers should add the sheet models to the ORD index.

Notes & Quantities

The notes and quantities sheets for TDOT are typically placed in the 2 and 3 series sheets at the front of the plan set. Occasionally, discipline specific notes sheets are placed in that discipline's sheet number scheme (e.g. EPSC Notes). The overall methodology for creating these sheets is not dependent on where the sheet will ultimately be placed in the index. As long as the primary item shown on the sheet is a word document or excel spreadsheet, this is considered a note and quantities sheet for purposes of this document. Each notes category should get its own file in ORD. For example, if there are going to be three (3) general notes sheets then all the sheets should be stored in the "SHT-General Notes.dgn" file. Special notes, however, would be in their own file named "SHT-Special

Notes.dgn." To create a notes file, designers should select the seed file named "Roadway Word.dgn." From there, the Fundamentals (ORD) training manual teaches how to place a word document into a sheet file. Word files should be embedded in the document because they are not separate design deliverables. The methodology is the same for quantities sheets however the seed file named "Roadway Excel.dgn" should be used when creating the sheet. Excel files should be linked to the original document because they are a separate design deliverable. After creating all the necessary sheets, designers should add the sheet models to the ORD Sheet Index.

Detail Sheets

Detail sheets, for the purposes of this document, are any sheet that contains mostly manually drawn details or depictions of something pertaining to the project. When creating these sheets, designers should use the seed file "Roadway Blank.dgn." The file name for the sheet file should be "SHT-Details.dgn." If a discipline specific details sheet is needed like Signal Details, the same seed file should be used to create the sheet, but the file name should have the discipline ahead of the word "details" like this: "SHT- Signal Details.dgn." In all cases, this file should contain all detail sheets for that section of the plans. After creating all the necessary sheets, designers should add the sheet models to the ORD Sheet Index.

Sign Schedule & Sign Structures

The sign schedule sheet seed is called "Sign Schedule sheet.dgn" and should be used when creating sign schedule sheets. The file containing all sign schedule sheets should be called "SHT-Sign Schedule.dgn." On the level "DES – SCRATCH – User 1" are dashed lines to aid designers in placing signs and text uniformly. This level has been setup to not print based on TDOT's Plot Configuration. Signs should be added to the legend using the place cell tool and accessing the "TDOT SIGNS.cel" cell library. The signs are set to place at a 50 scale; however, the sheet model is in 1:1 scale that is also in inches. For most roadway signs, an x & y scale of "0.05" should correctly size the cell to be placed in the sheet model. If users are trying to place a larger sign, it may be necessary to reduce the scale so that it fits on the sheet but is still legible. To start, there are six (6) sign schedule sheets within the seed, which should be enough for most projects. If more sheets are needed, copy one of the sheet models and rename it. After creating all the necessary sheets, designers should add the sheet models to the ORD Sheet Index and assign the correct starting sheet number.

The sign structures sheet seed is called "Sign Structures sheet.dgn" and should be used when creating sign structures sheets. The file containing all sign structures sheets should be called "SHT-Sign Structures.dgn." To start, there is enough drawing space and sheets for six (6) structures, which should be enough for most projects. If more drawing space and sheets are needed, designers should copy the representative sheet boundaries in the design model to give more drawing space and then copy a sheet model, adjust the reference location, and repeat to create as many sheets as needed. After creating all the

necessary sheets, designers should add the sheet models to the ORD Sheet Index and assign the correct starting sheet number.

Title Sheet

The Title Sheet file should be named “SHT-Title.dgn.” Designers should utilize the title sheet level filters to adjust what is shown based on the phase of the project. For additional details on how to create a title sheet, refer to the Fundamentals (ORD) training manual. After creating the sheet, designers should add the sheet model to the ORD Sheet Index.

Signature Sheet

Designers should create a file named “SHT-Signature.dgn” utilizing the “Signature Sheet.dgn” seed file. The signature template is placed to the left of the sheet and can be copied over and modified as needed. If a second sheet is needed, then designers should copy the first sheet model and rename the copy. For additional details on how to create a signature sheet, refer to the Fundamentals (ORD) training manual. After creating the sheet, designers should add the sheet model to the ORD Sheet Index.

Step 7: Create a PDF

To create a PDF, designers can access the ORD Sheet Index from any dgn file associated with that workset. Designers can select the **plan set** folder if they wish to print the whole set at once. If designers only want to print a specific folder like Present Layouts, then designers should just select that folder. If just one sheet is desired, then just select that sheet. After selecting the sheet(s) or folder(s) that are to be printed, designers should select “open print organizer”. Designers are then prompted to select a print style. TDOT has three pre-created print styles:

- TDOT PDF (Full Black and White)
- TDOT PDF COLOR (Full Color)
- TDOT PDF PERMIT

In these plot configurations four levels are currently set to not print:

- DES – SCRATCH – User 1
- DES – SCRATCH – User 2
- DES – SHEET – Light Grid
- DES – SHEET – Plot Shape

Note: *As the software and the TDOT workspace continue to evolve, the level “Default” will be added to this list. Designers should get in the habit now to never place design elements or anything intended to be printed on the default level.*

Selecting a print style will open the print organizer. From here, designers can continue to be selective of what is printed based on their selections. Pressing the print button will

open the print menu. From here designers can change the plot configuration if desired and adjust some other print functions. It is recommended that under the submit section designers set the “Submit as” function to “Separate print jobs”. Then, select the “Output File Names…” button and select “<sheet number>” as the output file naming expression. Designers should then select “Preview Names” to review the pdf names. Press ok to exit the preview. By default, the print job outputs to the “out” folder of the workset. Change the file path here to save the file somewhere else if desired. Lastly, designers should and then press ok to run the print job.

After the print job, designers should combine the separate PDF’s into a single PDF using a PDF editor.

Note: *ORD automatically combines a PDF comprised of multiple prints based on the folder organization of the ORD Index. For example, this results in all present layout sheets being grouped together and it ignores the alphanumeric order. Therefore it is recommended to use separate print jobs so that the order of sheets can be controlled before the total PDF is created.*

Step 8: Design Stage Progression & Revisions

As a project progresses from Preliminary Design to ROW Design to Construction, it is likely that some sheets in a previous phase will be renumbered in the current phase. When this happens, designers should copy the sheet number from the previous phase and place it in the sheet number block below it. This will carry the intelligent text link to the ORD index for the sheet number down to where the new number will be displayed. In the sheet number block from the previous phase, designers should edit the text, copy the text, and re-paste it to remove the data link.

If sheet revisions are necessary, designers should open the applicable sheet model and turn on the level “SHEET – Revision Text” and input the required information to document the revision.

Requirements for Model-based Design

The Department understands the value of Electronic Engineering Data (EED) and will examine the possibility of full digital delivery. There are various expected benefits of EED including:

- Increased productivity.
- Reduction in design errors.
- Conformance to industry trends of AMG (Automated Machine Guidance), eConstruction and Asset Management.

Furthermore, ORD CONNECT Edition products will allow designers to produce a product that retains the civil data and design intent through construction. As noted earlier, project deliverables will continue to be in the form of a **sealed PDF plan set**, which represents

the contractual legal document. The **3D model** will serve as **supplemental** data for the time being. The following sections provide general guidance and recommendations for the Department in regard to full digital delivery methods and will be refined as best practices evolve. It also important to note that standard naming conventions, data management and exchanges for each phase of the project development process are necessary when working with digital design models, as outlined in previous sections. Thus, the information herein will focus on defining roles and responsibilities, data management, milestone review, and deliverables for specific authorized uses for construction applications.

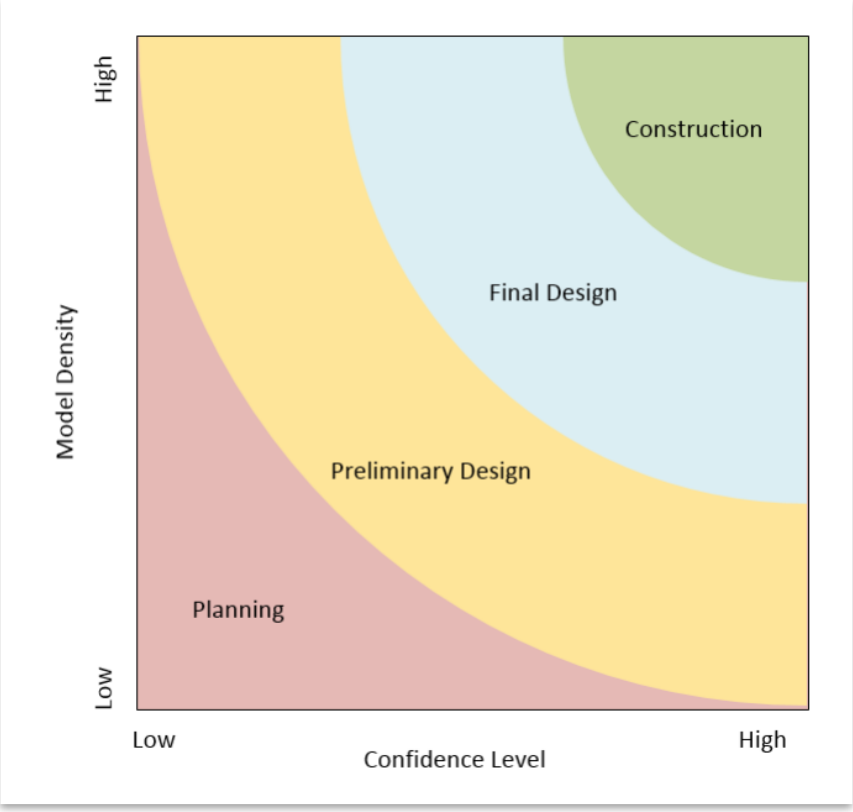
General Requirements

A key success factor when delivering digital design models is being able to communicate the purpose and need for each deliverable, which will let the design team know what content and level of development is needed for the model. **Level of development (LOD)** is defined as a qualitative designation that communicates the degree of engineering intent behind a 3D model. LOD can also communicate the authorized uses for which a model should be used for. Normally, the LOD will increase through the design development process. The concept of LOD can be broken down into two (2) categories:

1. Model density, which relates to how much detail is in the model
2. Confidence level, relates to how much uncertainty the model is based upon

Figure 2 illustrates the relationship between model density and confidence level as these two (2) categories pertain to LOD and 3D data usage.

FIGURE 2. FIGURE RELATIONSHIP BETWEEN MODEL DENSITY, CONFIDENCE LEVEL, AND 3D DATA USE[3]



Furthermore, LOD is traditionally broken down into LOD types or tiers in order to appropriately identify the level of information and the level of graphical detail for each. Generally speaking, LOD types communicate and define graphical and non-graphical details. Table 1 below provides a summary of recommendations for 3D model deliverables based on purpose and need. As the Department progresses in the model-centric design environment, this table could be used as a starting point to identify LOD types and associated criteria.

[3] Maier, Francesca; Chummers, Laura E.; Pulikanti, Shashank; Struthers, Jonathan Q.; Mallela, Jagannath; Morgan, Ralph H. (2017). "Utilizing 3D Digital Design Data in Highway Construction – Case Studies." Washington DC: Federal Highway Administration Retrieved from http://www.fhwa.dot.gov/construction/3d/hif17027.pdf.

TABLE 1. RECOMMENDATIONS FOR 3D MODEL DELIVERABLES BASED ON PURPOSE AND NEED

Purpose and Need of 3D Model	LOD Requirements	Final Design Model Deliverable

AMG – Grading (AMG-G)	• Geometrically and geospatially accurate 3D elements depicted in the roadway typical section, including: existing ground, proposed pavement design, clear zone, and side slope conditions (e.g., traveled way, shoulders, and side slopes)
	• Model typical templates should be designed at regular stations:
	  ○ 25-foot point interval in tangents.
	  ○ 10-foot point interval in curves.
	  ○ 5-foot point interval in transitions.
	• Model key station templates should be designed at horizontal and vertical transitions such as lane widenings, gore areas, superelevation critical sections and intersections.
	• May include feature attributes such as pay items.
		• Proposed terrain surface depicting either the proposed finished grade or subgrade (top of dirt) for the roadway traveled way and side slope conditions.
		• Civil geometry.
		• All line work showing all grade breaks.
		• Survey control file.

AMG – Paving (AMG-P)	• Geometrically and geospatially accurate 3D elements depicted in the roadway typical section, including: existing ground, proposed pavement design, clear zone, and side slope conditions (e.g., traveled way, shoulders, and side slopes)
	• Model typical templates should be designed at regular stations:
	  ○ 10-foot point interval in tangents.
	  ○ 2-foot point interval in curves.
	  ○ 2-foot point interval in transitions.
	• Model key station templates should be designed at horizontal and vertical transitions such as lane widenings, gore areas, superelevation critical sections and intersections.
		• Survey control files.
		• Civil geometry.
		• All line work showing all grade breaks or/and surfaces showing structural pavement limits.

Purpose and Need of 3D Model	LOD Requirements	Final Design Model Deliverable
	• May include feature attributes such as pay items.	

Constructability Reviews (CR)	• Geometrically and geospatially accurate 3D elements depicted in the roadway typical section, including: existing ground, proposed pavement design, clear zone, and side slope conditions (e.g., traveled way, shoulders, and side slopes)
	• Model typical templates should be designed at regular stations:
	  ○ 25-foot point interval in tangents.
	  ○ 10-foot point interval in curves.
	  ○ 5-foot point interval in transitions.
	• Model key station templates should be designed at horizontal and vertical transitions such as lane widenings, gore areas, superelevation critical sections and intersections.
	• May include feature attributes such as pay items.
		• Existing topography (3D solids representing existing features from lidar if available).
		• Civil geometry model(s).
		• Corridor model(s).
		• Drainage model.
		• Utility model(s).
		• Structure model(s) (if available).

Public Outreach Visualization (VIZ)	• Photorealistic. ○ Traditionally, basis of original ground survey is unknown, or there is a high probability that original ground survey does not reflect field conditions.	• Still images and videos.

Survey Layout (STAKING)	• 2D/3D line work representing centerline, right-of-way lines, and grade break lines modeled.
	  ○ 25-foot point interval in tangents.
	  ○ 10-foot point interval in curves.
	  ○ 5-foot point interval in transitions.
		• Alignments, profiles, 3D line strings, and survey control files.

Quantity Take-offs	• Alignments, surfaces, and 2D/3D line work. • PowerGEOPAK or ORD model.	• Alignments, surfaces, and 2D/3D line work. • ORD model.

Purpose and Need of 3D Model	LOD Requirements	Final Design Model Deliverable
Risk Construction Management (RCM)	• Specified work breakdown structure (WBS) of activities. • Critical path method (CPM) schedule. • Geometric models with 3D solids depicting the elements needed for WBS activities. While the 3D model does not need to be of high survey accuracy, it can serve as the basis for the 4D model. Design team should discuss specific requirements with visualization team creating the 4D model.	• Corridor model(s) as needed for sequence of construction activities and stages. • 4D model showing sequence of construction work based on the work breakdown structure (WBS) and activities used for critical path method (CPM) progress schedules as still images and/or videos.

Roles and Responsibilities

It is recommended to define roles and responsibilities for the project team during the scoping phase, at which time the project delivery team should start defining the model development requirements.

The three key stakeholders in a model-centric project delivery process are the parties who create (author), use, and manage the model. The model author(s) are responsible for developing one or many elements of a 3D model (e.g. geometry, corridors, drainage, utilities). The model user is any party consuming information derived from the model directly or indirectly (construction, geotech, contractor, etc.). Lastly, the responsible party to manage the model is that single point of contact for all inter-disciplinary and model-related issues. This person is typically known as a digital delivery coordinator or building information modeling (BIM) coordinator, and he/she is responsible for managing the collaboration and quality control processes, as well as other duties to ensure successful use of 3D models during project delivery.

Furthermore, a Digital Delivery or BIM Coordinator is the keeper of all documentation and may serve as the quality control (QC) manager during the design phase, but also post-award this person keeps track of all digital design model information in what is known as a Model Inventory, which is simply a document (e.g. spreadsheet) that contains information regarding the level of detail and files associated with project design data. The Digital Delivery Coordinator should:

- Work with the project delivery team to facilitate multi-disciplinary collaboration (constructability and environmental reviews, etc.).
- Communicate the purpose and need for the models (automated machine grading, visualization, etc.).
- Document the responsibilities of stakeholders (who creates and review content).
- Select the tools to be used for collaboration and data management.
- Describe the model development specifications (survey, design and utility accuracies and digital as-built requirements).
- Identify strategies for managing risk, responding to changes, and resolving any issues or discrepancies.

Model Development Specifications

Level of Development and Accuracy Specifications

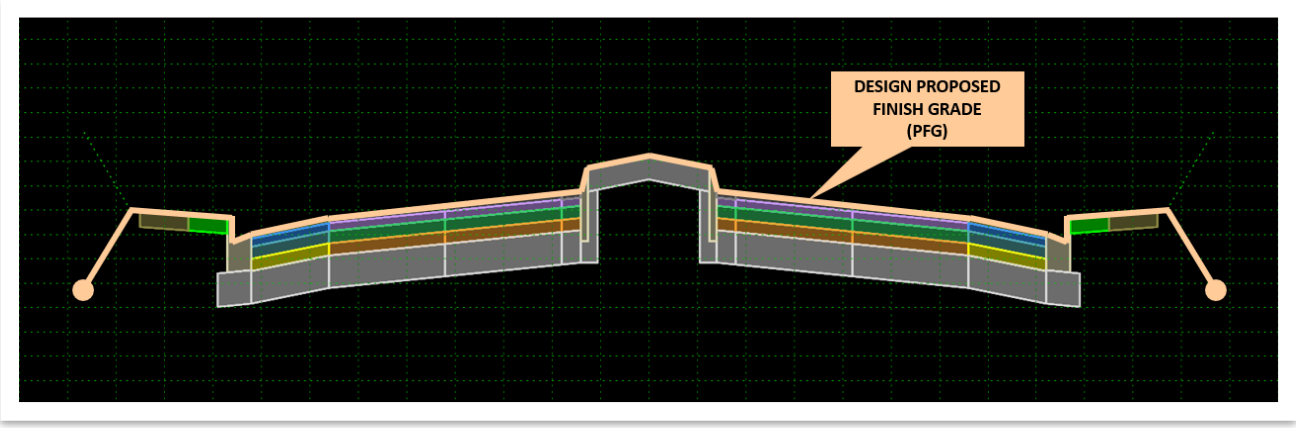
The Level of Development (LOD) and Level of Accuracy (LOA) specifications define the reliability of the information contained in the model in terms of design intent and certify survey accuracies for existing conditions. LOD specifications are used to communicate allowable authorized uses; whereas, LOA specifications are used to manage risk during construction. As noted in an earlier section, it is recommended that the Department

consider creating standard LOD & LOA specifications to mitigate risk during construction. TDOT may define LOD specifications for the following authorized uses:

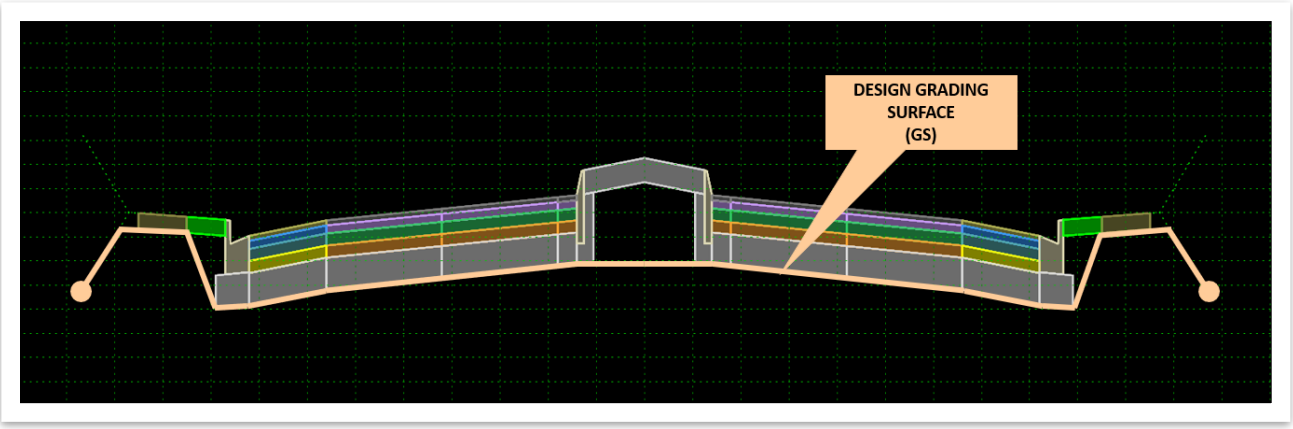
- **Existing terrain condition survey models (field and aerial):** Holistically, the survey deliverables will contain all features currently collected by field and aerial surveys, the terrain model, preliminary alignment, and 3D utility model. It is also important to discuss minimum survey accuracies that will support the intended use.
- **Automated machine guidance (AMG) construction models:** These models should contain sufficient information for contractors to use with their AMG equipment for grading and paving. It is recommended that TDOT engages with the contracting community to understand what information and types of files are preferred.

  In general, AMG grading equipment requires a digital terrain model (triangulated network) that represents the surface to be graded. It is typical to deliver a terrain surface that represents the **design proposed finished grade**. However, contractors may request one of the additional three (3) surfaces shown below, which have been setup in the TDOT ORD workspace as graphical filters. AMG models for paving typically require alignment and profiles and 3D breaklines representing the edge of structural pavement. AMG is mostly used for concrete paving, but it may also be used for 3D milling and asphalt paving.

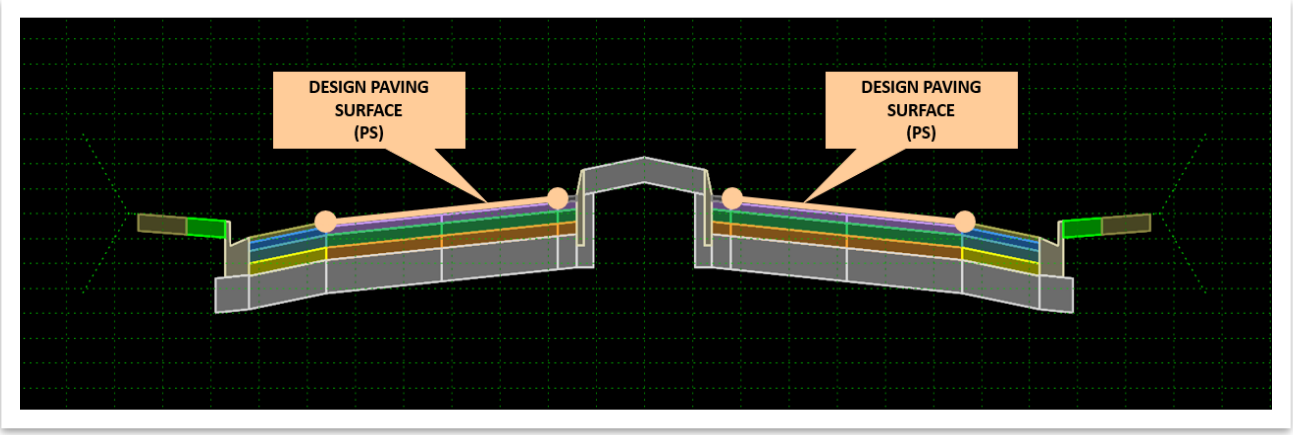
  Design **Proposed Finished Grade**



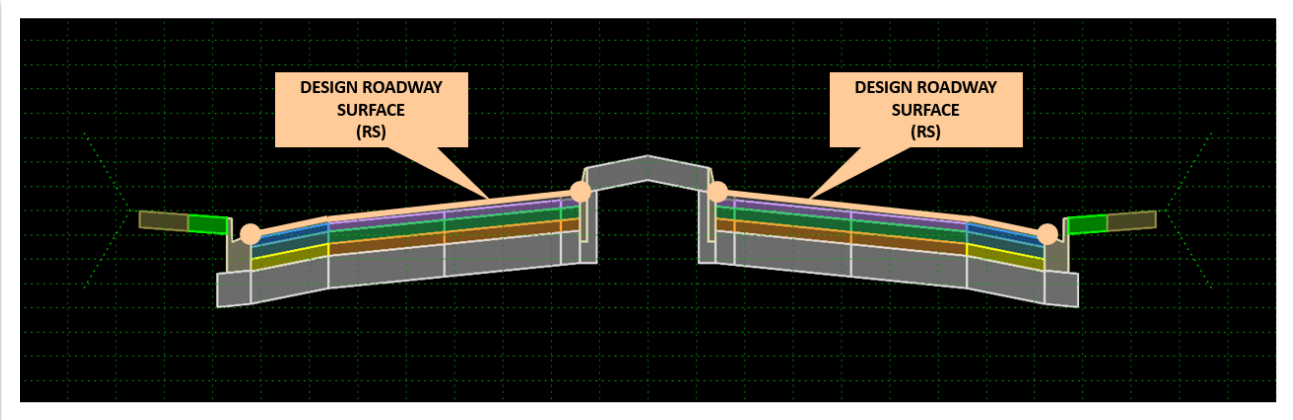
Design **Grading** Surface



Design **Paving** Surface



Design **Roadway Surface**



- **<u>Roadway models for plan production</u>:** Models intended for plan production should contain sufficient information for designers to develop plan, profile and cross section sheets as required for a contract plan set. Examples of elements

included in the roadway model are alignments, profiles and corridor geometry (e.g. superelevation, pavement and shoulder design, fill/cut slopes, ditches). These models may also include certain visualization elements, such as 3D guardrail and traffic control devices (e.g. barrels and cones).

- **Closed-drainage system models:** Drainage models are intended to help engineers design and analyze hydraulic properties of the drainage network. In addition to the calculations required for hydraulic design and analysis, ORD creates a physical model of the drainage network. This model can be referenced to the roadway model to present a complete picture of the roadway project.
- **Utility models:** These models include existing and proposed utilities modeled as 3D shapes. Existing and Proposed utilities should be modeled utilizing the SUDA tools. Bentley is making other tool enhancements that will make modeling **existing** utilities more efficient in the future.
- **Roadway models for multi-disciplinary collaboration:** Models intended for multi-disciplinary collaboration are a collection of different models developed by different disciplines. Typically, these include roadway, drainage, utilities and structure models.

Level of Visualization (LOV) Guidelines

It is important to specify what level of visualization is expected for different applications. The more photo-realistic and content added to the visualization, the higher the cost. The software used for 3D design has many standard tools available to the designer to do basic visualization, such as visual textures based on 3D template components and showing striping. However, to create visualization outputs, the software requires an additional level of effort to set lighting, placing cameras in the view, and rendering images. This sophisticated level of visualization is usually reserved for public outreach and communication of high-profile projects.

Project Data and Documentation during Design

A sample **Model Inventory** spreadsheet (**Appendix E. Sample Model Inventory**) has been drafted to help design staff document project design data. The Model Inventory lists the project manager, authors, model reviewers, and other project information. The Model Inventory is also used to document the quality assurance performed on the design files for each stage of the project development phases (e.g. preliminary, right-of-way, and construction). It is recommended that TDOT uses this document to keep track of model elements and their certified LOD. The Model Inventory is like the “read me” file to communicate what information is contained in the model, such as:

- Information about elements modeled.
- LOD and LOV specifications for each modeled element.
- Authorized uses.

- Name of responsible party for developing the model.
- Certified survey quality and project combined scale factor.
- Any comments or notes.

The final Model Inventory document should be stored in a centralized location, such as the project's FileNet folder or SharePoint location so that authorized users have the ability to edit information in the file. A sample of a model inventory has been developed for TDOT's consideration in Appendix E. Sample Model Inventory.

Milestone Reviews

It is highly recommended to conduct milestone reviews to involve applicable project stakeholders throughout the lifecycle of the project. These collaborative reviews allow the project team to find issues in a virtual environment early in the process to avoid costly changes late in the process or during construction. Navigator is Bentley's platform for model review and collaboration. TDOT may want to consider investigating the use of this tool for model-based reviews.

Model Changes During Field Operations

It is important that a protocol for documenting changes and managing versions of the files is defined. The Digital Delivery Coordinator should follow the project throughout construction to assist operations with adjusting the model without compromising the construction schedule. If a Digital Delivery Coordinator is not available during construction, it is important to define which changes constitute the necessity to go back to the *Design* team for revisions.

Deliverables submitted through FileNet should have a folder structure for the most current models, including a corresponding list of changes from version to version. Having a "historical" folder is often used to keep a complete model history of the changes pertaining to the project. Furthermore, a model inventory for post-award changes should be kept up-to-date with changes, including the reason for the changes, when the changes occurred, who updated and certified the model, and for what the model was used. This is important for resolving any discrepancies between layout, placement, and inspection.

Contract Requirements for 3D Models

It is recommended that the Department use legal contract language for both consultants and contractors when indicating the design and use of 3D models on all projects, including alternative delivery. The sample text below should be reviewed by TDOT's Legal Division but is intended to serve as a guide for developing specific text for each entity.

Consultant Requirements

The Tennessee Department of Transportation (TDOT) plans to use 3D engineered models for design authoring and development of contract plans, contractor use of

Automated Machine Guidance (AMG) for grading and paving, and construction inspection and verification. Contract Plans for Highway Construction should continue to be produced electronically in accordance with the Department requirements. The consultant should work closely with the Department to develop a Project Execution Plan (PxP) that:

- Defines authorized uses of specific engineering data.
- Roles and responsibilities for different tasks.
- Specifications for survey accuracies to meet model development requirements and authorized uses.
- Protocols for data management, validation, and information exchanges.
- Requirements for collaboration tools; and strategies for managing risks.

Contractor Requirements

The Tennessee Department of Transportation (TDOT) plans to use 3D engineered models for design authoring and development of contract plans, contractor use of Automated Machine Guidance (AMG) for grading and paving, and construction inspection and verification. The Department shall authorize the engineering digital data files distributed with the contract plans as specified in the Contract Model Inventory.

The contractor shall comply with the Department's Standard Specifications for Road and Bridge Construction and contract requirements. The governing ranking in case of any discrepancies between the engineering digital data and the contract plans is:

1. Addendum letters
2. Standard drawings
3. Supplemental specifications
4. Standard Specifications
5. Special provisions
6. Model
7. Project plan and drawings

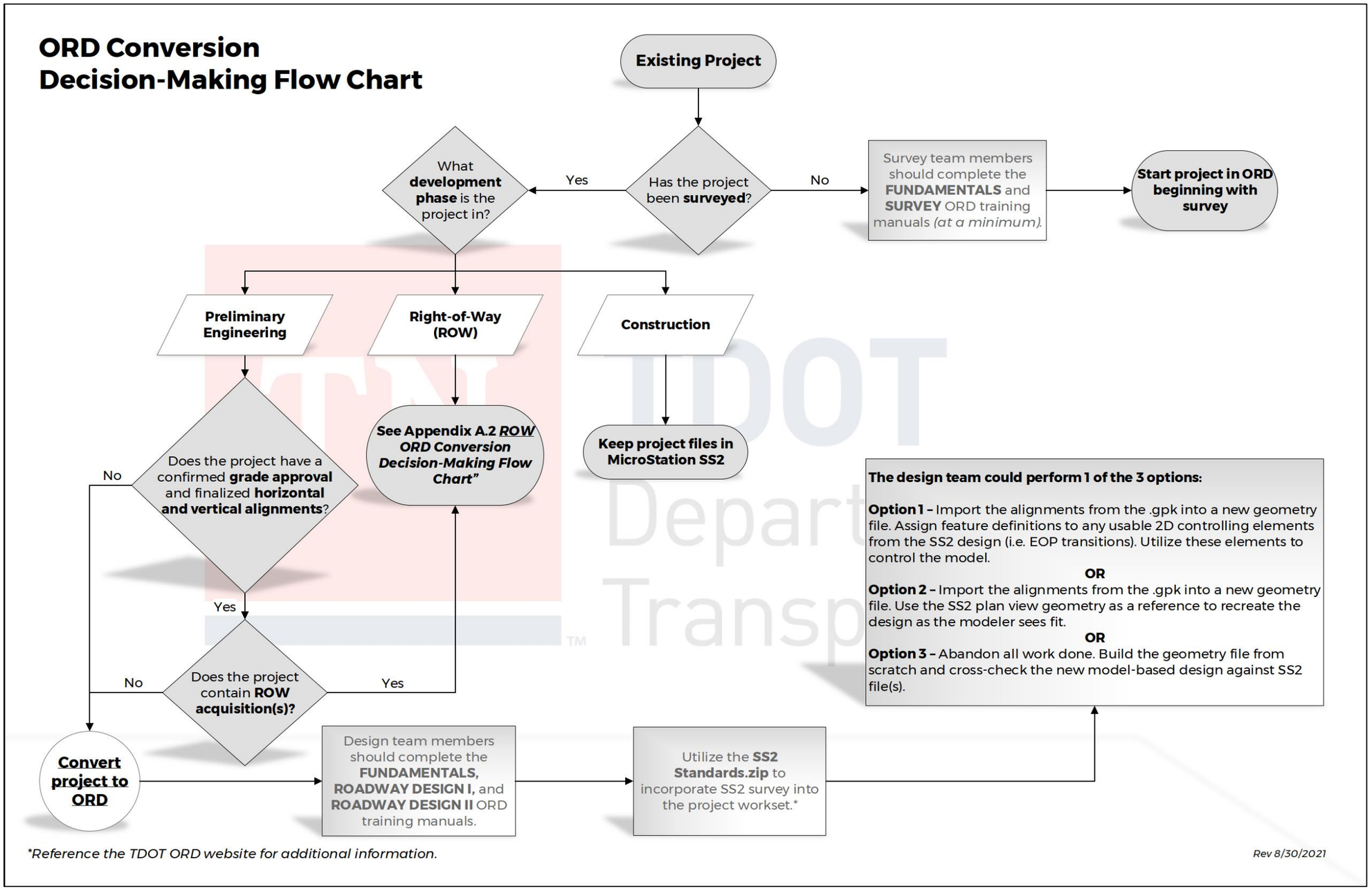
Upon contract award, the contractor shall participate in a pre-construction meeting with Department staff and consultants to develop a Project Execution Plan (PxP) to define roles and responsibilities, as well as protocols for validating and documenting any field changes to the models and manage data files.

Model Revision History

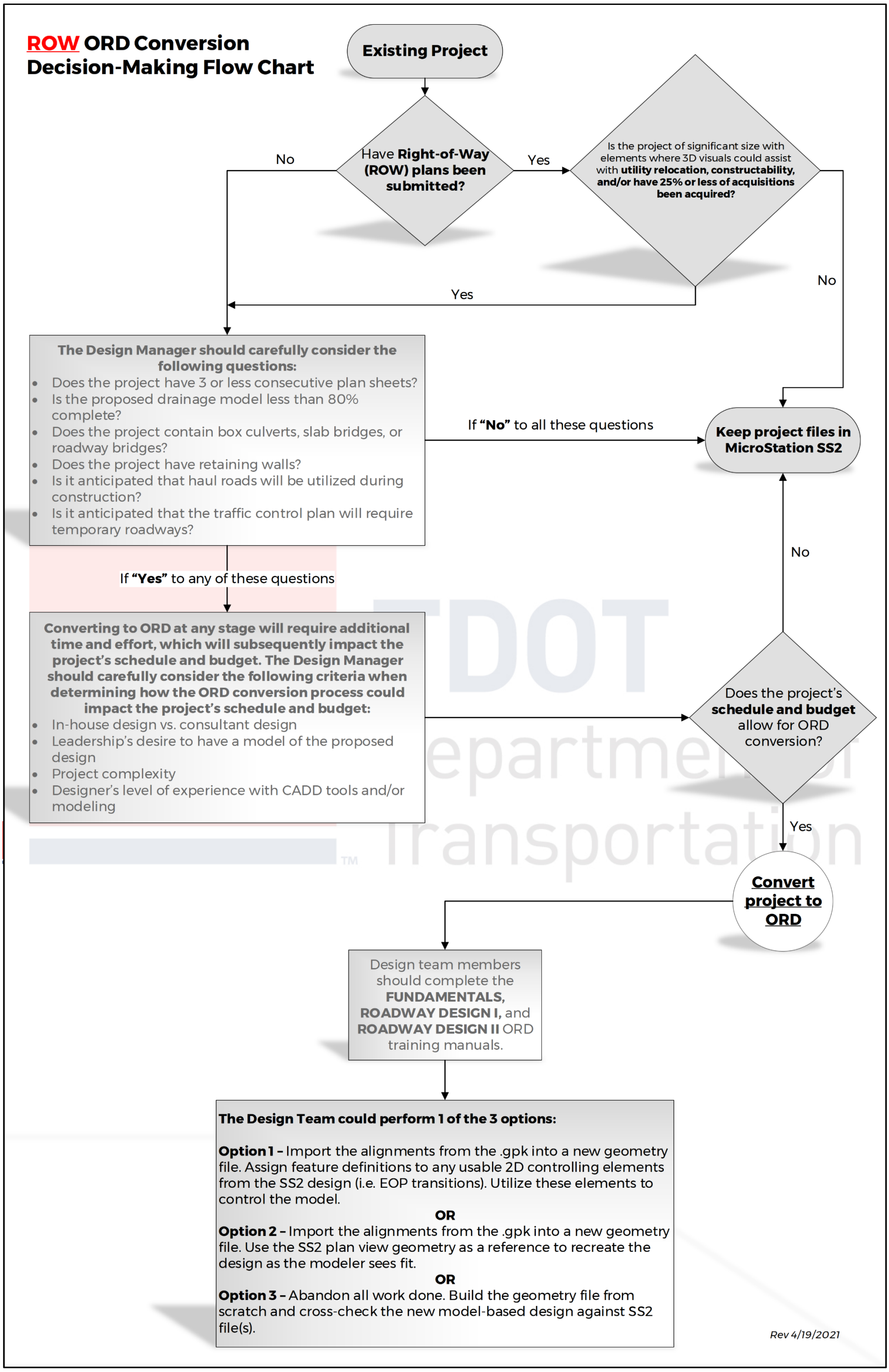
DATE (MONTH/YEAR)	AUTHOR/EDITOR	IB #	SECTIONS MODIFIED

Appendix A. Conversion Guidance

Appendix A.1. ORD Conversion Decision-Making Flow Chart



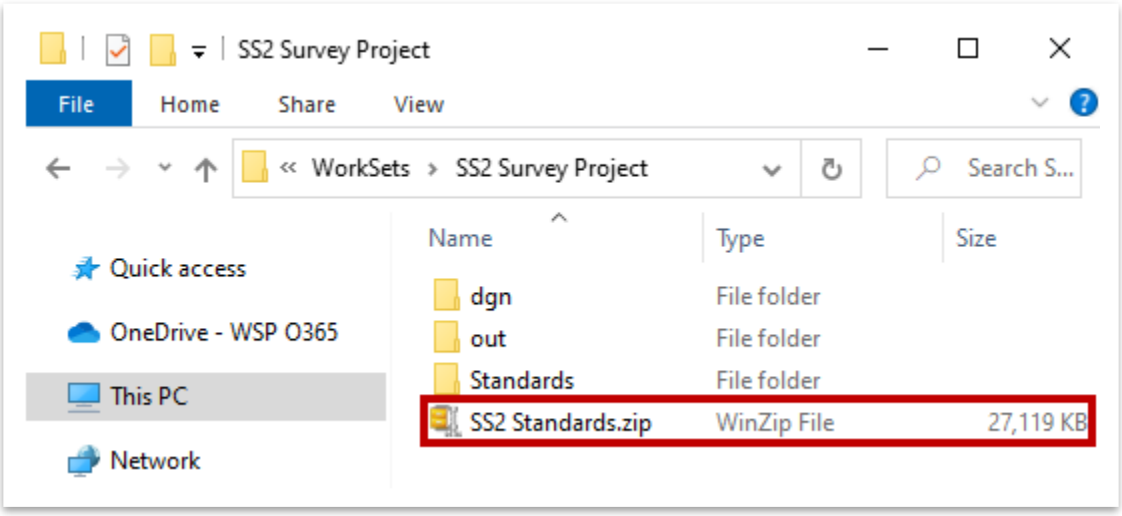
Appendix A.2. ROW ORD Conversion Decision-Making Flow Chart



Appendix B. SS2 Survey Implementation into ORD

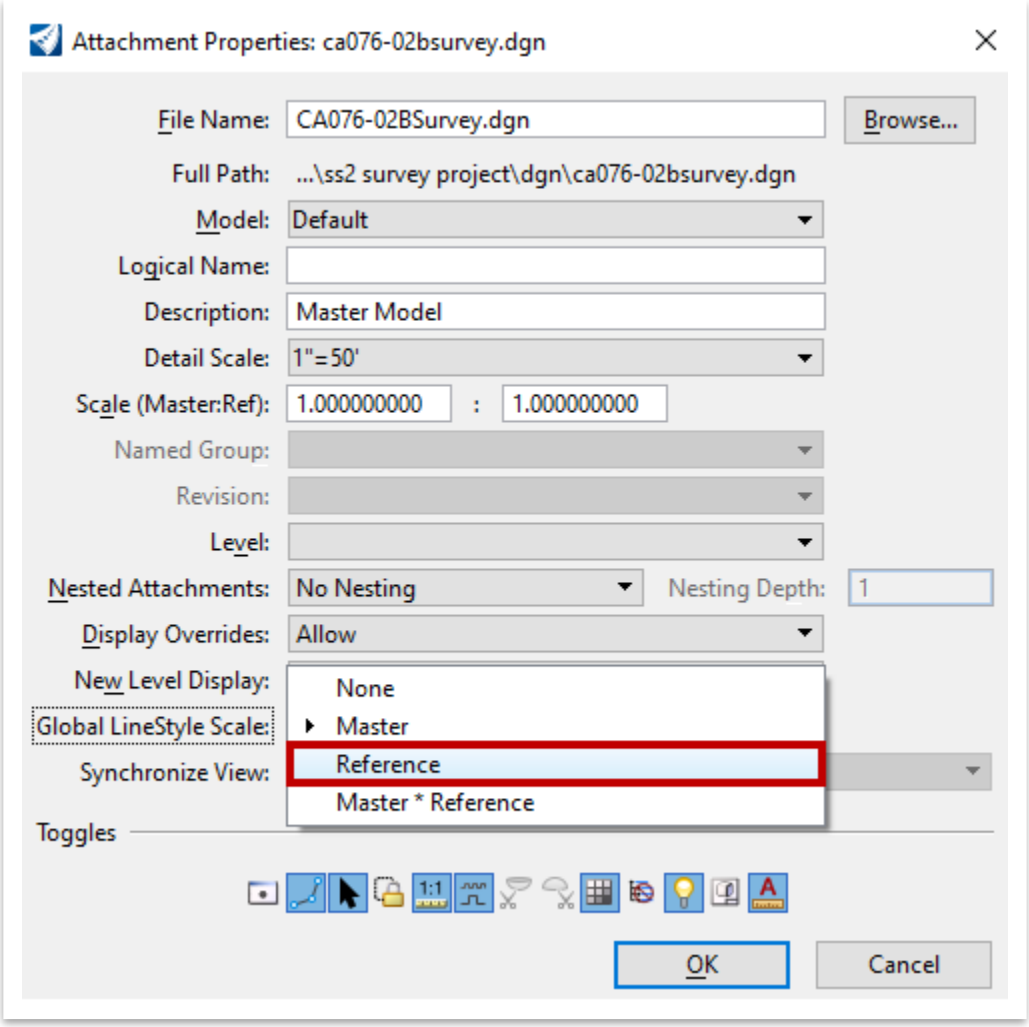
If utilizing a SS2 survey in an ORD project, you will need to incorporate the **SS2 Standards.zip** file into your project **workset**. This will allow the correct visualization of all 2D SS2 survey graphics and annotation. Once incorporated, you will see the applicable TDOT SS2 custom linestyles and be able to utilize the SS2 filters. The example workset created in this document is called **SS2 Survey Project**.

1. Within **File Explorer**, open your project workset and paste the **SS2 Standards.zip** file into the main folder: **C:\ProgramData\Bentley\OpenRoads Designer CE\Configuration\WorkSpaces\TDOT_Standards\WorkSets\SS2 Survey Project**.



2. Right click on the zip file and select **WinZip >> Unzip to Here**. **Note:** If you don't have **WinZip**, use any zip extractor but make sure to unzip to the main workset folder. Once extracted, go ahead and delete the zip file.
3. The extraction will place the SS2 **dgnlib** (levels and filters) and three **.rsc** files (custom linestyles) into the applicable subfolders within the **Standards** folder. Any file opened or created under this **SS2 Survey Project** workset will now contain the necessary workspace elements to display the 2D SS2 survey elements properly.
4. Within your ORD design file (e.g. Alignment), attach the SS2 **survey.dgn** file as a reference. If you examine the utility linestyles, for example, they will still show a solid linestyle and look incorrect. You need to apply some additional updates, which will be covered in the next steps.

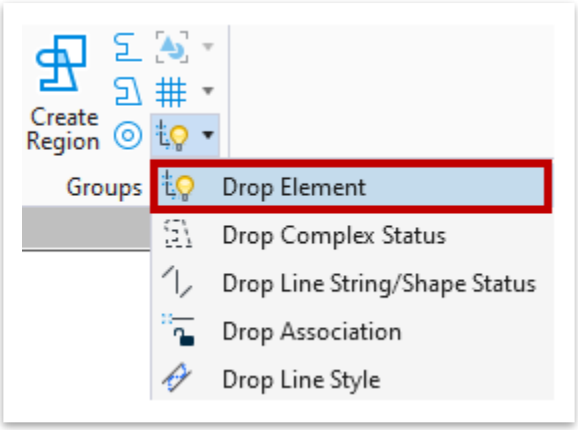
5. Within the **References** window, right click on the survey reference file and select **Settings**. Within the **Attachment Properties**, change the **Global LineStyle Scale** from Master to **Reference** and then click **OK**.



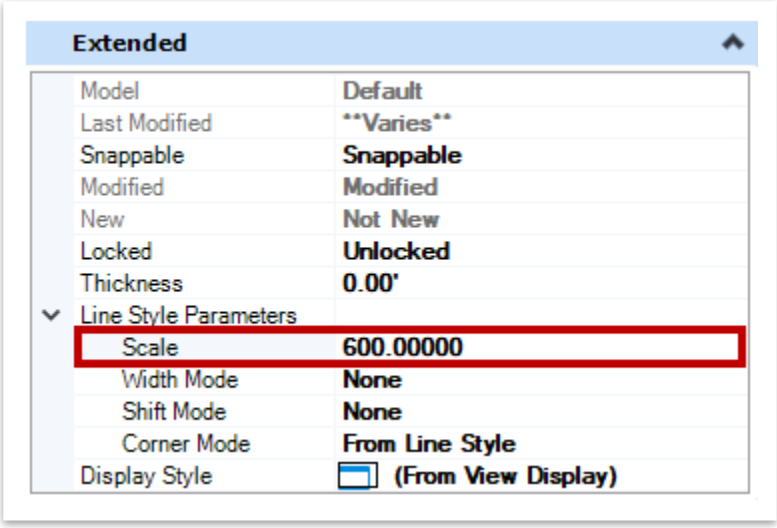
6. Notice that the majority of the SS2 linestyles update and now look correct. One of the caveats between SS2 and ORD is if the custom linestyle is not unique on both platforms, the ORD version and scale will override the SS2 version. There are currently **twelve** SS2 survey linestyles that share the same name in ORD. While the correct linestyles appear in the referenced SS2 survey file, the scale is incorrect. **Note:** The twelve linestyles might get renamed in ORD, pending further investigation. For now, apply the scaling as shown in Steps 7-9.

    - Brush Line
    - City Line
    - County Line
    - Forest Line
    - Hedge
    - Property
    - Railroad
    - ROW Fence Ex
    - State Line
    - SUE Gas Line
    - SUE Water Line
    - Swamp Line

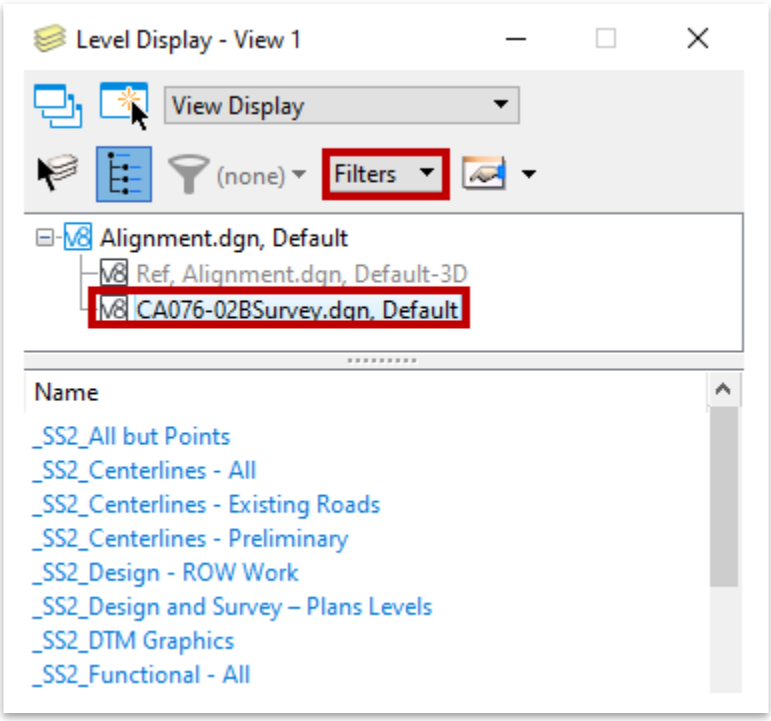
7. Within the **References** window, right click on the survey reference file and select **Activate**. Turn off all survey elements other than the linestyle(s) that you want to scale. In order to apply a mass scale, there cannot be any **complex elements** or else you won't see the applicable field in the **Properties**. Line strings are also problematic, but you can still utilize them. However, you'd have to scale all line strings separately from the lines. The simplest thing to do is select all and open the **Drop Element** tool (**Survey >> Drawing >> Groups**) and left click anywhere within the drawing window.



8. With the applicable lines still selected, open the **Properties** window (if not already open) and scroll down to **Extended >> Line Style Parameters >> Scale**. Change the scale to the desired value, based on your design scale. This example utilizes a 50 scale design, so a scale of **600** would be used. **Note:** A 20 scale design would use 240 and a 200 scale design would use 2400.



9. Within the **References** window, right click on the survey reference file once again and select **Deactivate**. If you want to apply a **Filter** to the survey reference file, open the **Level Display** and highlight the reference file. Select **Filters** and notice that the applicable SS2 filters appear at the top of the list with an underscore. All ORD filters are listed further below.



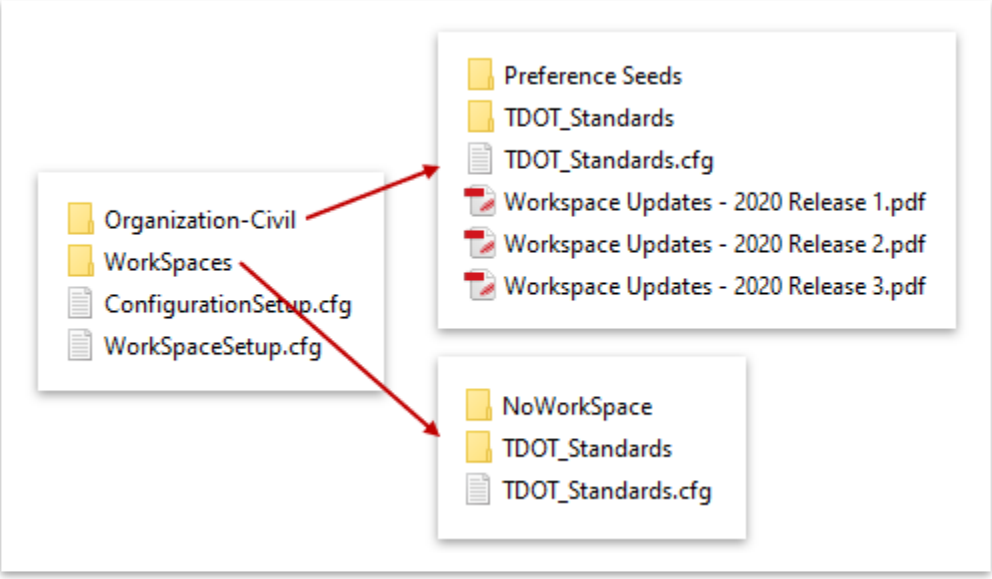
Appendix C. Workspace Installation Guidance (External Users)

The **Configuration.zip** file can be extracted from the TDOT OpenRoads Designer webpage. The referenced zip file will be located in a table and accessed via downloadable, clickable link, as shown in the figure below.

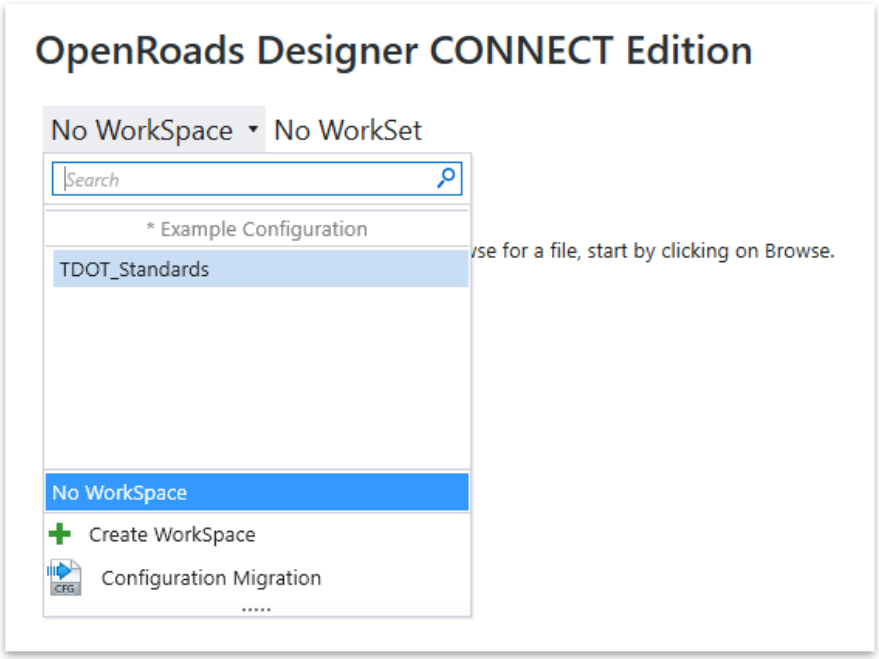
Name	Description	Size	Date
TDOT ORD Workspace (Revision Notes)	This file is for those who have **OpenRoads Designer Release 3 only**. Others **should not** download. **Download Location:** In the same drive as ProgramData\\Bentley\\OpenRoads Designer CE	281 MB	06/07/2021

Within the configuration folder, there is an **Organization-Civil** folder. It contains a **TDOT_Standards** folder and a **TDOT_ Standards.cfg** file which contain the workspace setup. These files should not be touched or edited.

The TDOT configuration folder should be extracted to the following location and **REPLACE** the default Bentley configuration folder: **C:\ProgramData\Bentley\OpenRoads Designer CE**. You should see the folders below if done correctly.

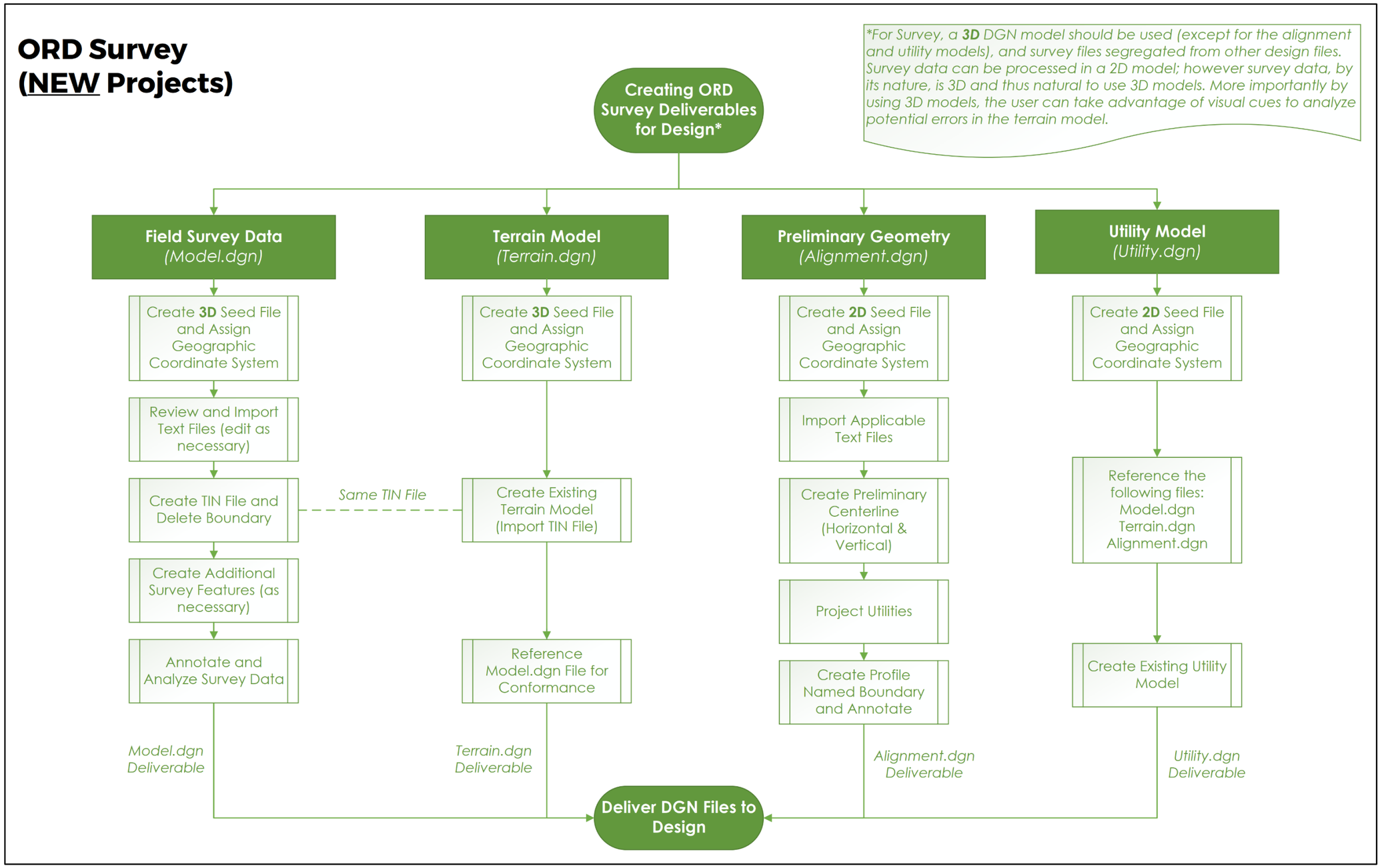


Once the user launches ORD, they should only see the TDOT workspace option (**TDOT_Standards**) and then be able to create a new Workset.



WARNING: **Be sure to make a copy of your existing MicroStation V8i (SS2/SS10) dgn file(s) if you plan to open them in ORD. Information may be lost as some aspects of ORD files are not reverse compatible with MicroStation SS2/SS10 files.**

Appendix D. Survey Deliverables Process



Appendix E. Sample Model Inventory

Tennessee Department of Transportation
Model Inventory

County: _____

PIN: _____

Description: _____

Design Manager: _____

Surveyor of Record: _____

Project Phase: _____

Version of Workspace Used: _____

Project Combined Scale Factor: _____

Survey LOA: _____

Comment Legend: *Designer Comments*
Reviewer Comments

Category	Element	Sub-Element	LOD	LOV	Primary and Secondary Uses	Designer Name	Reviewer Name	Reviewer Checked	Date of Review	File Name (s)	Project File Location	Comments or Notes
Proposed	**Geometry**	Alignments										
		Profiles										
		Superelevation										
		3D Breaklines										
		Other										
	Roadway Corridors	Mainline										
		Entrances and Driveways										
		Intersections/Roundabouts										
		Interchanges										
		Cross-overs										
		Other										
	Proposed Terrains	Proposed Finished Grade										
		Alternate Surfaces										
	Earthwork	Corridor Excavation and Embankment										
		Entrances and Driveways										

		Borrow/Waste Pits										
		Pipe Excavation										
		Other										
	Drainage	Closed Storm Network										
		Culverts and Pipes										
		Other										
	Utilities	Utility Model 1										
		Utility Model 2										
		Utility Model 3										
	Appurtenances	Sign Structures										
		Lighting										
		On-structure Drainage										
		Conduits										
Existing	**Existing Survey**	Aerial Survey										
		Field Survey										
		Lidar Survey										
		Control Points										
		Other										
	Structures	Superstructure										
		Substructure										
	Appurtenances	Sign Structures										
		Lighting										
		On-structure Drainage										
		Conduits										
	Utilities	Drainage										
		Gas										
		Water										
		Sanitary Sewer										
		Etc.										
	Context	Terrain										
		Roadways										

		Buildings										
		Landmarks										